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ABSTRACT

On the instruction of the Council of Ontario Universities, the Advisory Committee Engineering (CODE), conducted a planning assessment for doctoral work in chemical engineering. Emphasis is placed on a summary of general evaluations; recommendations; chemical engineering as a discipline; nature and objectives of the PhD programs; analysis of the Ontario situation; the job market; and information concerning chemical engineering at McMaster University, University of Ottawa, Queen's University, University of Toronto, University of Waterloo, University of Western Ontario, and the University of Windsor. For a study on electrical engineering, see HE 005 873. (MJM)

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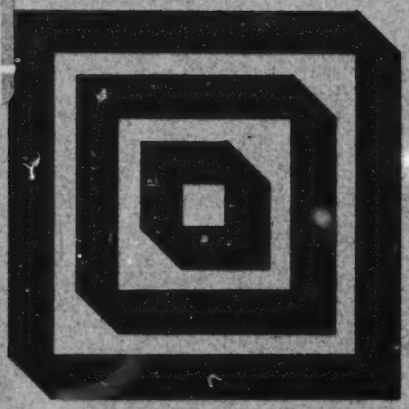

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HE005-862

Advisory Committee on Academic Planning
Ontario Council on Graduate Studies

Council of Ontario Universities
Conseil des Universités de l'Ontario

PERSPECTIVES AND PLANS FOR GRADUATE STUDIES

11. ENGINEERING 1974*

A. CHEMICAL ENGINEERING

Advisory Committee on Academic Planning
Ontario Council on Graduate Studies

74-13

* The status of this report is given in Item 2 of the statement of principles, on page 1.

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ENGINEERING 1974

A: Chemical Engineering

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This report deals with a planning study of doctoral work in engineering, which was conducted in several portions corresponding to the various disciplines within engineering. The report is in six volumes. Volume A deals with chemical engineering, B with electrical enginnering, C with metallurgical and materials engineering, D with mechanical engineering, E with industrial engineering, and F with civil engineering. Each volume contains the COU and ACAP reports for engineering as a whole together with the consultants' report and other material appropriate to one of the disciplines. The COU report will be in three parts: Part I dealing with the recommendations approved in June 1974 and dealing with most of the fields, Parts II and III to appear later dealing with mechanical and industrial engineering, and with civil engineering respectively. This volume, printed in the summer of 1974, contains only Part I.

FOREWORD

As a consequence of a study of engineering education in Ontario (described in more detail in the subsequent ACAP report) the Council of Ontario Universities called for a planning assessment of PhD programmes in engineering to be carried out by ACAP in cooperation with CODE.

The Advisory Committee on Academic Planning (ACAP), as presently constituted, was established by the Ontario Council on Graduate Studies at the request of the Council of Ontario Universities in January, 1971. The Advisory Committee's terms of reference were directed broadly toward the effective planning and rationalization of long-term graduate development in Ontario's universities both at the level of individual disciplines and at a more general level. The Advisory Committee's activities are based on the premise that graduate work is the one area of university activity in which specialization among universities, cooperative arrangements and comprehensive planning are most necessary.

The disciplinary planning process involves a discipline group composed of one representative from each university with an interest in graduate work in the planning area. In the case of engineering, CODE was also involved in a way described in the ACAP report. The discipline group assists in defining the precise academic boundaries of each study, and prepares a commentary on the consultants' report.

The final decision on consultants for the planning study is made by ACAP. The consultants are requested to make recommendations on programmes to be offered in Ontario, desirable and/or likely enrolments, the division of responsibility for programmes among universities, and the desirable extent of collaboration with related disciplines.

While the consultants' report is the single largest element in the final report on the planning study, ACAP considers the statement of each university's forward plans to be most significant. These forward plans are usually outlined prior to the planning study, and are used as a basis for comments from the universities concerned on the consultants' report.

On receipt of the consultants' report, and comments on it from the disicpline group and the universities, ACAP begins work on its own recommendations for submission directly to the Council of Ontario Universities. COU considers the input from all sources, and prepares the position of the Ontario university community.

The following report is one of a series of disciplinary planning studies carried out by the Advisory Committee on Academic Planning and to be published by the Council of Ontario Universities. The emphasis of the report is on forward planning, and it is hoped that the implementation of COU's recommendations will help to ensure the more ordered growth and development of graduate studies in Ontario's universities.

Council of Ontario Universities
Conseil des Universités de l'Ontario

Report and Recommendations concerning Doctoral Studies in Engineering - Part I

On the instruction of the Council of Ontario Universities, the Advisory Committee on Academic Planning, in cooperation with the Committee of Ontario Deans of Engineering, has conducted a planning assessment for doctoral work in engineering. This arose from the need to re-examine the recommendations concerning PhD work which appeared in Ring of Iron. The background to the study, the procedures followed and the planning techniques used are described in the ACAP report and are not repeated here. The resultant report from ACAP is attached together with the consultants' reports, the comments by the discipline groups, the comments of the individual universities, and the comments of CODE. It is important for the reader to read the attachments in order to understand the recommendations in this Report from COU. COU will issue subsequent parts to this report dealing with mechanical, industrial and civil engineering.

The Council received the ACAP report and supporting documentation on April 11, 1974. The content of the ACAP document was debated on April 11, on May 3, and on June 7, 1974. As a result of these discussions this Report and Recommendations was prepared and approved by the Council on June 7, 1974. The report is addressed to the Ontario Council on University Affairs and the universities of Ontario.

The following principles have been adopted and will apply to this and all other COU Reports arising out of assessments.

1. Discipline assessments by ACAP should form the basis for planning by the universities of their development of graduate studies, particularly PhD programmes. On the basis of these assessments, COU should make its own recommendations on currently embargoed programmes. Each university must retain the freedom and responsibility to plan and implement its own academic development. However, the universities in embarking on a cooperative planning process have signalled their intentions of cooperating with the COU recommendations.

2. Universities generally plan their emphases in graduate study on the bases of related departments, not of single departments. Initially the sequential nature of the discipline planning assessments makes this difficult. However, by the summer of 1974 there will have been assessments of most of the social sciences, all of the physical sciences, engineering doctoral work, and a number of professional areas. On the information and recommendations then available, each university should be able to make decisions concerning its support of graduate programmes in these areas. Amendments to university responses to the individual discipline planning assessments may then be made in the wider context of a group of related disciplines and amendments to COU's original Reports on an individual discipline may be required.

3. The first concern in planning is to review the quality of graduate opportunities and of students in Ontario universities and to make judgements about how to proceed or not proceed based on quality considerations. The procedures have made use of highly qualified independent consultants who have no direct interest in the universities in Ontario. Accordingly, COU feels bound to accept their judgements about quality where they are stated clearly unless unconvinced that their conclusions about quality are consistent with their evidence. COU's recommendations in the case of programmes which are of unsatisfactory or questionable quality will call for discontinuation or the carrying out of an appraisal, if the continuation of the programme is not crucial to the province's offerings. In some cases, however, there may be a particular need for the programme and the appropriate recommendation will be to strengthen it, with an appraisal following that action. It is also possible that if there were found to be too large a number of broadly-based programmes there could be a recommendation to discontinue the weakest; in this case, an appraisal for a more limited programme might be relevant.

4. A second consideration is the scope of opportunities for graduate work in the discipline. Do the Ontario programmes together offer a satisfactory coverage of the main divisions of the discipline?

5. Numbers of students to be planned for will depend on the likely number of applicants of high quality and in some cases may relate to an estimate of society's needs. Such estimates may be reasonably reliable in some cases and not in others. If the plans of the universities appear to be consistent with the likely number of well-qualified applicants and there is either no satisfactory basis for estimating needs or there is no inconsistency between a reasonable estimate of need and the universities' plans, then COU will take note of the facts without making recommendations on the subject of numbers.

   If the numbers being planned for by the universities are grossly out of line with the anticipated total of well-qualified students, or a reliable estimate of needs, COU will make appropriate corrective recommendations. Depending on the circumstances, these may call for a change in the total numbers to be planned for and indications of which institutions should increase, decrease, or discontinue. The recommendations in serious cases may need to specify departmental figures for each university for a time. If the numbers being planned for are insufficient, the recommendations may call for expansion, or new programmes, and may have implications for both operating and capital costs.

   Unless there are exceptional circumstances, the recommendations concerning enrolment will not call for a university to refuse admission to any well-qualified student who wishes to work in a field in which that university offers a programme and in which it has the capacity to accommodate the student.

6. The quality of graduate programmes is partly dependent on size, and for each programme, depending on how it is designed and its scope, there is a minimum size of enrolment below which quality may suffer. That number cannot be expressed for the discipline as a whole but only for individual programmes depending on their purpose, their resources and their design.

7. Universities will be expected to notify COU if they intend to depart from the COU Report in any way which they believe might have a significant bearing on the provincial plan.

8. Appraisals arising as the result of assessments are to be based on the standards but not necessarily the scope of the acceptable programmes in the province.

General observations concerning engineering doctoral work

1. Ontario is unlikely to over-produce engineering PhD's in the next five years. However, the student body contains too large a proportion of non-Canadians. Qualified Canadians should be encouraged to seek the engineering PhD.

2. Doctoral students should be selected on the basis of high academic standing and research potential.

3. "Inbreeding" is a problem, with many students obtaining three degrees from one university.

4. Faculty members, whether or not engaged with doctoral students, should have the facilities and opportunities to engage in research and in work with industry.

5. The scope for inter-university and university-industry cooperation is considerable and should be exploited.

6. The quality and state of development of the Ontario doctoral programmes are variable. Some are very good and have gained international recognition.

7. Some universities are organizing (or reorganizing) doctoral study on a division of specialization other than that provided by the "traditional" engineering departments. In two of the smaller faculties this is a central factor in the planning, but increasing cross-departmental activity is also in evidence elsewhere.

Actions by COU

1. COU has abandoned a planning number of 450 doctoral students and advises the universities to plan on the assumption that the doctoral enrolment will remain roughly constant for the next five years. Although there is a need for engineers with doctorates in Ontario, graduate student enrolment will level off due to a lack of top quality students. Canadians must be attracted in increasing numbers in order to maintain enrolment at the present level.

2. COU requests that CODE report annually to COU on enrolment and employment opportunities.

3. COU requests that ACAP arrange for each engineering discipline group:
(1) to monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students (to ACAP for transmission to COU);

(2) to report annually to ACAP on the universities previously attended by the newly admitted graduate students of each department.

4. COU requests CODE, after consultation with the discipline groups, to develop proposals for collective methods of making information on graduate work in all Ontario universities readily available to the engineering students, and to inform ACAP of the action taken.

5. COU requests OCGS to examine existing university guidelines on part-time doctoral work and its supervision.

6. COU request that ACAP arrange for an annual report to OCGS from each university on the time taken for each graduating student to complete his doctoral studies.

7. COU requests ACAP to examine the available documentation on civil engineering, to reach its own judgements on the basis for a report, after soliciting assistance from the discipline group and the universities, and to prepare its report to COU containing recommendations for the future of civil engineering doctoral work. This should be submitted by December 31, 1974.

8. COU requests that ACAP arrange for the metallurgical and materials engineering discipline group to present a report to ACAP on university actions taken to correct identified weakness in certain fields of study.

Recommendations

It is recommended that:

1. Universities, CODE and discipline groups take steps to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

2. The universities attempt to maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

3. The universities, the provincial government, and granting agencies examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined.

4. All doctoral thesis examining committees have an examiner external to the university.

5. At present, there not be any specific engineering doctoral part-time programmes but rather that part-time or non-resident doctoral work be done by individual arrangement. Experimentation in methods of carrying on part-time work is to be encouraged and might lead in future to the creation of specific part-time programmes. It is also recommended that the research topic of any student accepted on a part-time basis be in a field in which the professors in the department have expertise.

University Recommendations

Engineering was split into five separate assessments, one for each of the five traditional fields of engineering. Two universities, Western Ontario and Windsor, do not administer their doctoral engineering work along these lines but rather on an interdisciplinary basis that cuts horizontally across engineering. For this reason, these two universities are being dealt with separately and not as part of the more standard approach evident in the five assessment reports. Similarly, Guelph also is included in this section.

It is recommended that:

6. The University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. If a favourable appraisal is not obtained by the end of October, 1976, admission of new students should then be suspended.

7. The University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977, if a favourable appraisal has not been obtained.

8. The involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the university begin doctoral work in agricultural engineering at a time in accordance with the university's plans, subject to normal appraisal procedures.

Chemical Engineering

This section deals with doctoral work in chemical engineering at McMaster, Ottawa, Queen's, Toronto and Waterloo.

It is recommended that:

9. The departments consider grouping their research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

10. McMaster University continue its doctoral work in chemical engineering according to its plans.

11. The University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

12. Queen's University re-evaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the university considers appropriate. If a favourable appraisal has not been received by October, 1976, enrolment of new students then be suspended.

13. The University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to the desirable mobility of its bachelor's graduates for graduate work elsewhere and to the desirability of grouping of research areas. The University of Toronto is requested to report to COU through ACAP by June, 1975, on action taken in regard to this Recommendation.

14. The University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

Civil Engineering

The consultants' report is unfortunately inadequate for planning purposes.

It is recommended that:

15. The embargo on the funding of any new programmes in civil engineering continue until COU has accepted a report from ACAP dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted by ACAP by December 31, 1974.

Electrical Engineering

This section deals with doctoral work in electrical engineering at Carleton, McMaster, Ottawa, Queen's, Toronto and Waterloo.

It is recommended that:

16. The discipline group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and

make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

17. Carleton University continue its doctoral work in electrical engineering according to its plans.

18. McMaster University continue its doctoral work in electrical engineering according to its plans.

19. The University of Ottawa plan the reorganization of its doctoral programme in electrical engineering and put forward the programme for appraisal. If a favourable appraisal has not been obtained by the end of the fall term 1976, admission of new students should cease. In the meantime, enrolment of new students should be restricted to the digital communications systems and large-scale systems fields.

20. Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields should be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

21. The University of Toronto continue its doctoral work in electrical engineering according to its plans.

22. The University of Waterloo continue its doctoral work in electrical engineering according to its plans.

Metallurgical and Materials Engineering

This section deals with doctoral work in metallurgical and materials engineering at McMaster, Queen's, Toronto and Waterloo.

It is recommended that:

23. The universities take steps to increase the activity in the ceramics, glasses, and polymer fields of study in the province.

24. McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and make a report to COU through ACAP in the fall of 1975 on the following suggestions for improvement:

    a) recruitment of students with physics and chemistry backgrounds
    b) strengthening of the extractive metallurgy faculty
    c) collaboration with the University of Toronto

25. Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors from other departments. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish

to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975, if a favourable appraisal is not obtained.

26. The University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto consider broadening the programmes and it is requested that the university report to COU through ACAP by September, 1975, on any progress made in this direction.

27. The University of Waterloo continue its doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Mining Engineering

It is recommended that:

28. Queen's University continue its doctoral work in accordance with its plans.

General

It is recommended that:

29. In view of the acceptance of these recommendations by the Council of Ontario Universities and the completion of Part I of this planning assessment, the Ontario Council on University Affairs request the Minister to remove the embargo on doctoral work in Engineering (except for Mechanical, Industrial and Civil Engineering at Carleton, McMaster, Ottawa, Queen's, Toronto and Waterloo), in accordance with the original announcement of the Minister that new graduate programmes would be embargoed until, for each discipline, a planning study has been conducted.

Notes concerning the recommendations

Re: Recommendations 1, 2, and 3

The background to these important recommendations appears on pages 13 and 14 of the ACAP Report.

Re: Recommendation 7

Presumably the programmes submitted for appraisal will be the three divisional programmes which are replacing the departmental programmes.

Re: Recommendation 16

Other engineering discipline groups may also find this a valuable suggestion.

Re: Recommendation 19

This differs from the recommendation in the ACAP Report because the University subsequently decided to carry out a re-assessment of the future direction of the department.

Re: Recommendation 25

Queen's has reported to COU its intention to enlarge its programme in extractive metallurgy.

June 7, 1974.

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ADVISORY COMMITTEE ON ACADEMIC PLANNING

ONTARIO COUNCIL ON GRADUATE STUDIES

REPORT TO THE COUNCIL OF ONTARIO UNIVERSITIES ON ENGINEERING DOCTORAL PLANNING ASSESSMENTS

JUNE 7, 1974

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For each planning assessment (Chemical, Civil, Electrical, Mechanical, Metallurgical, and Industrial) there are appended:

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Appendix B - Discipline Group Response

Appendix C - University Comments

Appendix D - Procedure of Planning Study and Terms of Reference

Appendix E - Discipline Group Membership

Appendix F - Roles of ACAP and of Discipline Groups

Appendix G - Curricula Vitarum of the Consultants

Appendix H - CODE Response

I. RECOMMENDATIONS

General Recommendations

C1

It is recommended that COU abandon the quota of 450 doctoral student enrolment in 1974-75, and plan on roughly the present enrolment for the next five years, assuming greater interest by Canadian students in engineering graduate work. If this interest does not materialize, the enrolment will undoubtedly drop. In any case, it is recommended that CODE be asked to report annually to COU on enrolment and employment opportunities.

C2

It is recommended that steps be taken to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

C3

It is recommended that the universities maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

C4

It is recommended that the universities, the provincial government, and granting agencies consider the remarks of the consultants and examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined; increased contacts between faculty and industry could lead to increased industrial support.

C5

It is recommended that each Discipline Group monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students to ACAP for transmission to COU.

C6

It is recommended that all doctoral thesis examining committees should have an examiner external to the university.

C7

It is recommended that each Discipline Group and CODE develop proposals for making information on graduate work in all Ontario universities readily available to the engineering students, in some collective way and inform ACAP of the action taken. Each Discipline Group should report annually on the university last attended by the graduate students in each department.

C8

It is recommended that at the present any part-time or non-resident doctoral work should be by individual arrangement and that experimentation in this type of programme be encouraged. It is also recommended that the research topic of the student accepted on a part-time basis be in a field in which the professors in the department have expertise. It is recommended that OCGS examine existing university guidelines in this area.

C9

It is recommended that the universities report to ACAP (for OCGS) each year on the time taken by each graduating student to complete his doctoral studies.

University Recommendations

C10

It is recommended that the University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. In case a favourable appraisal is not obtained by October, 1976, admission of new students should then be suspended.

C11

It is recommended that the University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes (presumably these will be the three divisional programmes which are replacing the departmental programmes), for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977, if a favourable appraisal has not been obtained by that date.

C12

It is recommended that the involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the University begin doctoral work in agricultural engineering at a time in accordance with the University's plans, subject to normal appraisal procedures.

Chemical Engineering

C13

It is recommended that the departments take note of the consultants' recommendation 10 to group research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

C14

It is recommended that McMaster University continue its doctoral work in chemical engineering according to its plans.

C15

It is recommended that the University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

C16

It is recommended that Queen's University reevaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the University considers appropriate. If a favourable appraisal has not been received by October 1976, enrolment of new students should be suspended at that date.

C17

It is recommended that the University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to Recommendation C7 regarding mobility of its graduates and to Recommendation C13 concerning grouping of research areas. It is recommended that the University of Toronto report to COU through ACAP by June, 1975, on action taken in regard to this Recommendation.

C18

It is recommended that the University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

Civil Engineering

C19

It is recommended that COU recommend the continuance of the embargo on the funding of any new programmes in civil engineering until COU has accepted

a Discipline Group report dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted to ACAP by December 31, 1974.

Electrical Engineering

C20

It is recommended that the Discipline Group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

C21

It is recommended that Carleton University continue its doctoral work in electrical engineering according to its plans.

C22

It is recommended that McMaster University continue its doctoral work in electrical engineering according to its plans.

C23

It is recommended that the University of Ottawa continue to offer a doctoral programme in electrical engineering restricted to theses in digital communication systems and large-scale systems. This limited programme is to be appraised as soon as possible. Enrolment of new students should cease as of December, 1975 if a favourable appraisal has not been obtained.

C24

It is recommended that Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields would be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

C25

It is recommended that the University of Toronto continue its doctoral work in electrical engineering according to its plans.

C26

It is recommended that the University of Waterloo continue its doctoral work in electrical engineering according to its plans.

Mechanical Engineering

C27

It is recommended that Carleton, McMaster and Queen's Universities continue their doctoral programmes in mechanical engineering and during the coming year give careful consideration to the feasibility of a stronger development of foci of interest in the special areas of strengths suggested by the consultants. The Universities are requested to report to COU and OCGS, through ACAP, during the Fall of 1975, on the results of these considerations.

C28

It is recommended that, if the University of Ottawa wishes to reactivate a doctoral programme in mechanical engineering, it give careful consideration to allowing some further maturing of the department before applying for appraisal.

C29

It is recommended that the University of Toronto continue its doctoral programmes in mechanical engineering in its Department of Mechanical Engineering and the Department of Aerospace Studies and Engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities of the Department of Mechanical Engineering on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

C30

It is recommended that the University of Waterloo continue its doctoral programme in mechanical engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

Metallurgical and Materials Engineering

C31

It is recommended that the universities take note of the consultants' recommendations 1, 2, 3b and 3c, dealing with the weakness in certain fields of study in the province and that the Discipline Group report to ACAP on any action taken in consequence of these recommendations.

C32

It is recommended that McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and noting the strength attributed to these programmes by the consultants, make a report in the fall of 1975 on the following suggestions for improvement:

a. recruitment of students with physics and chemistry backgrounds

b. strengthening of the extractive metallurgy faculty

c. collaboration with Toronto.

C33

It is recommended that Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors in other departments as suggested in the consultants' report. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975, if a favourable appraisal is not obtained.

C34

It is recommended that the University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto give careful consideration to the consultants' recommendations concerning broadening the programmes and it is recommended that the University report to COU through ACAP by September, 1975, on any progress made in this direction.

C35

It is recommended that the University of Waterloo continue its engineering doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Mining Engineering

C36

It is recommended that Queen's University continue its doctoral work in mining engineering in accordance with its plans.

Industrial Engineering and Systems Design

C37

It is recommended that the University of Toronto continue its doctoral work in human factors engineering, management information systems and operations research.

C38

It is recommended that the University of Waterloo continue its doctoral programme in systems design.

II. BACKGROUND AND PROCEDURE

In June, 1968, the Committee of Presidents of the Universities of Ontario, after a meeting with the chairman of the Committee on University Affairs, decided that a comprehensive review of engineering education in Ontario should be undertaken. The Committee of Ontario Deans of Engineering (CODE) was requested to draw up plans for such a study, and this proposal was approved by the Committee of Presidents on November 15, 1968. The objective was to create a master plan which could be used as a guide for rational growth of engineering education during the 1970's. Such a plan should endeavour to provide for the highest attainable quality, the best use of resources, opportunity for innovation, and maximum freedom of choice for students.

This study culminated in the report Ring of Iron prepared by a commission chaired by Philip Lapp.

The report was received by the Committee of Presidents in January, 1971. A process of review of the report's recommendations was established, CODE prepared a brief based on statements of views submitted by each university concerned and by each Faculty of Engineering. Briefs were prepared also by the Ontario Council on Graduate Studies (OCGS) and the Association of Professional Engineers of Ontario. On October 5, 1971, the Council of Ontario Universities (COU) considered Ring of Iron and the briefs and prepared a statement of recommendations to the universities and to CUA.

COU accepted a number of the Lapp recommendations without change, others with amendments and rejected some. Broadly speaking, the recommendations to do with undergraduate matters were accepted or modified slightly. The graduate area of the report was more controversial, but here also some recommendations were accepted. The most significant of the recommendations concerning graduate study, as approved by COU, are:

> "The criteria of acceptability of graduate degrees in engineering should be recast in order that a thesis based on design or systems synthesis may be suitably assessed. This could involve the establishment of a new degree at the doctorate level."
>
> "Both universities and industries should recognize joint appointments as part of the career structure of their senior staff; these appointments should be increased as far as possible..... By this we understand a system of part-time appointments."
>
> "Over the next two years the estimated graduate enrolment of 2,000 full-time equivalent students for 1970-71 be reduced by 17%, after which graduate enrolment should be limited to a number equal to the previous year's bachelor graduations. The enrolment figure applies to the engineering departments as identifed in Ring of Iron".

"The recommendation that the number of PhD students enrolled be reduced to 450 per year is fully supported by all groups including COU. However, COU, along with CODE and OCGS, recommends that the figure of 450 be the target for 1974-75, rather than for 1973-74, for reasons related to avoiding large fluctuations in enrolment as explained in the OCGS critique."

"The Lapp report recommends specific numbers of PhD enrollees for each of the universities including discontinuance of the PhD enrolment in certain universities. COU feels that the reasons for the numbers chosen or for the elimination of certain doctorate programmes are not fully documented in the Lapp report. COU also agrees with CODE and OCGS that attention must be given to the numbers of doctorate enrollees by discipline as well as by university. For these reasons COU recommends that for the year 1972-73 doctorate enrolment be reduced in each university below the projected figure for 1971-72 by a pro rata percentage in order to provide 612 doctoral candidates (the number required to achieve the target of 450 in 1974-75). Preliminary acceptance of the OCGS method for reducing PhD enrolment (by limiting new PhD enrolments to achieve a total system number of 450 by 1974-75) is based on plans for discipline planning assessments respecting PhD programs to be initiated immediately and completed as rapidly as possible. Such assessments will be carried out by ACAP in cooperation with CODE; they are to incorporate capability, demand and quality correlates, and are to be used to provide specific recommendations on changes for the total PhD enrolment, and for the division of the enrolment amongst universities and amongst disciplines. The assessments are to incorporate a review of the effects of the pro rata reductions in 1972-73, and to recommend a mechanism for continuing review of PhD enrolments."

On receipt of this instruction from COU, ACAP and CODE established a liasion committee (Ayers, Dillon, Ham, Johnson, Shemilt, McIntosh, Preston) which drafted procedures for the assessments. It may be noted that the committee considered a model in which the assessments were based, not on the five traditional departments found in engineering faculties, but rather on interdepartmental areas of research; the practical difficulties of conducting the assessments led the committee to recommend the five-fold subdivision actually used.

The procedure developed in this way was approved by ACAP on March 17, 1972, and by COU on April 7. The procedure (except for minor data amendments) is that in Appendix D to this report. In writing to indicate its

approval CODE expressed their understanding that two objectives would be met:

"1. To provide a rational basis for doctoral work in engineering and for confirming or modifying the limitation on enrolment suggested by Lapp.

2. To conduct a really effective assessment of the quality of our current doctoral programmes."

CODE went on to emphasize the need of adequate resources to obtain the best consultants.

In order to begin the planning assessments, the ACAP/CODE liasion committee called a meeting of members of the five Discipline Groups (Chemical, Civil, Electrical, Mechanical, and Metallurgical Engineering). This meeting on April 12, 1972, indicated a good deal of faculty resistance to the conduct of the planning assessments and uneasiness about some perceptions of some aspects of the approved procedures. This resulted in a delay in mounting the assessment. CODE suggested a Coordinating Task Force, consisting of two members of CODE, the chairman of each Discipline Group, and a member of ACAP could review the procedures. ACAP advised COU to agree to this request and the COU executive did so on June 9, 1972. This Task Force held meetings on June 29, July 27, September 1, September 25, November 29, 1972 and March 19, 1973. It suggested two slight additions to the procedures as approved earlier by COU. These were approved by COU on September 25, 1972. The Task Force also produced a document clarifying some aspects of the procedure in detail, and a statement of some educational philosophies concerning doctoral study. These documents are referred to in the terms of reference of the consultants. The Task Force also advised ACAP (and so did universities) on how to take into account for planning purposes those doctoral programmes in Faculties of Engineering which did not fall obviously into the fields covered by one of the five consulting teams. It was eventually decided that:

a) both the metallurgy and the mechanical engineering consultants would be asked to consider the metallurgical work within the Department of Mechanical Engineering at Waterloo

b) no advice from external consultants would be sought on the doctoral programme in mining engineering at Queen's

c) a small-scale "planning assessment" involving two consultants would be carried out in industrial engineering and systems design

d) in view of the fact that all current doctoral students at Guelph are in hydrology and that the field of agricultural engineering is also proposed, the civil engineering consultants would be asked to consider the Guelph doctoral work, with the understanding that if they so wished ACAP would facilitate a consultation for them with someone in a department of agricultural engineering

e) the mechanical engineering consultants be asked to consider the doctoral work at the University of Toronto Institute of Aerospace Studies and in aeronautical engineering at Carleton, with the request that they consult also with another of the ACAP consultants (on the Electrical Engineering team) who had expertise in some of the UTIAS work outside mechanical engineering and also with an aerospace specialist

f) advice on the future plans of the Department of Management Science at Waterloo would be sought from the consultants in the planning assessment in Administration, Business and Management Science, with a comment also provided by the consultants on industrial engineering.

g) no special arrangements were needed in connection with biomedical engineering at Toronto since the corresponding institute has no graduate programme of its own, and the future doctoral plans are covered in the statements from each of the associated departments.

Item f will be dealt with in a later report. The remainder are covered in this report. The mechanical engineering consultants informed ACAP that they did not require the assistance suggested in item e.

In October, 1972, CODE proposed that a study be carried out, under the aegis of the newly established Canadian Engineering Manpower Council, and with financial support from a number of agencies, in order to make recommendations about "supply and demand" for engineering doctorates. This would be expected to be of great value to the planning assessments. ACAP agreed to this suggestion, provided funds towards the costs, and incorporated reference to the study into the instructions for the consultants. In the event, the study proved rather disappointing; it is discussed later in this report.

As a result of suggestions from the Discipline Groups and after receiving comments from the Coordinating Task Force and from CODE, ACAP agreed on consultants at its meetings of September 7-8, October 13 and December 18, 1972. The consultants who finally acted were:

Chemical Engineering:	Dean P. Grenier of Université Laval, Dean W. R. Marshall of the University of Wisconsin, Professor L. Yaffe of McGill University
Civil Engineering:	Professor W.W . Eckenfelder of Vanderbilt University Mr. B. V. Martin of Alan M. Voorhees and Associates Ltd., Professor G. G. Meyerhof of Nova Scotia Technical College, Dr. J. L. Boulet of Hydro-Quebec.
Electrical Engineering:	Professor A. D. Moore of the University of British Columbia, Professor M. E. Van Valkenberg of Princeton University, Dr. M. P. Bachynski of RCA Research Laboratories

Mechanical Engineering: Professor H.W. Emmons of Harvard University, Dean G. Ford of the University of Alberta, Dr. R. D. Hiscocks of the National Research Council of Canada, Professor S.G. Mason of McGill University

Metallurgical Engineering: Professor J.J. Jonas of McGill University, Professor T.B. King of the Massachusetts Institute of Technology, Professor W.S. Owen of Northwestern University and M.I.T., Dr. W.B. Lewis of Atomic Energy of Canada Ltd.

Brief curricula vitarum appear in Appendix C. In each case, the last named person played the role of a senior Canadian from outside the discipline.

The consultants held their first meetings at various dates in April and May, 1973 and in each case met with the appropriate Discipline Group, arranged the schedule of visits, discussed their character and had general discussion with the Discipline Group about the task before them. The visits took place in the two or three months following these meetings.

The consultant teams each submitted a draft report in September, which was the subject of oral discussion with the Discipline Group at a meeting within a few days of the receipt of the draft. Each consultant team then submitted its report. These reports were sent for comments to the universities, to the Discipline Groups and to CODE, each of which sent comments to ACAP at various dates in November, December and January.

A subcommittee of ACAP began consideration of the report to COU, before all the comments were in hand and continued its work through March, 1974, reporting regularly to ACAP and receiving instructions. Early in its meetings the committee identified some points on which further information and reactions were required. In particular, the need for fuller advice from the consultants. was felt in the cases of civil and mechanical engineering. Such further advice was sought, with results discussed in the relevant sections of this report. ACAP also thought some further information would be helpful in connection with three of the universities and arranged meetings with officials of these universities and members of ACAP.

This report is based on the consultants' reports, the data collected for the study, the universities' comments and supplementary material from some of them, the Discipline Groups' responses, and the other documentation referred to in the procedures and terms of reference. The report sets out recommendations for COU on doctoral work in engineering in Ontario for the next few years.

As is required, ACAP presents this report directly to COU. It has also been transmitted for information to OCGS, CODE, and the Discipline Groups.

III. GENERAL RECOMMENDATIONS

This section of the ACAP report contains recommendations that are of general concern to all of engineering. Some of these recommendations have been mentioned consistently in all the reports while others, although found in only one report, are applicable to all doctoral programmes.

Enrolment and Manpower Forecasts

In the summer of 1973, the Canadian Engineering Manpower Council released its report entitled Supply and Demand for Engineering Doctorates in Canada. This report was partly financed by ACAP and was given to all the consultant teams prior to their writing of their reports. It generally states that the supply of engineers in the next five years will exceed the demand.

A summary of the comments made by the engineering consultants concerning this report shows that they all independently disagree with the projections made in the CEMC report. They believe there has been no overproduction of PhDs to date and, in fact, there appears to be a shortage of metallurgical PhDs. Each team believes that the need for engineers will not decline, as predicted by CEMC but that the overall demand will continue and in actual fact, all but the civil engineering consultants believe it will increase.

ACAP had originally intended to publish a critique of the CEMC report. However, CODE in its repsonse to the engineering reports, Appendix H, has included a statement on this report covering all the points ACAP wished to make. ACAP's critique will not be reproduced, but we feel that the CEMC report is not an adequate basis for manpower planning in engineering. Since all the consultants agree that supply will not exceed demand but perhaps rather the reverse, the question of supply of qualified students must be studied. The main problem will be attracting Canadians into engineering graduate work. In 1972-73, of the 518 F.T. engineering PhDs, 28.6% were Canadian, 53.3% were landed immigrants and the remaining 18.1% were on student visas.

Changes in the immigration regulations make it harder to become a landed immigrant. Since one can no longer apply for landed immigrant status while in Canada, those that come on student visas will presumably return to their homelands. Coupled with this is another new regulation that a teaching assistantship is no longer classified as a job, thus making it harder to obtain landed immigrant status. Consequently, ACAP feels that the percentage of landed immigrants in graduate work will drop while the number of students visas will increase. Financial support for people on student visas is scarce. There are very few scholarships or bursaries open to them but in engineering they may be

supported from contract funds. In any case, there will be funds for only a few. Although Canada has a role to play in providing advanced technical education for the underpriviledged countries of the world, this should be kept to a reasonable level and should not exceed 30% of engineering doctoral enrolments.

CODE, on page H-9 of its response, states that "unless the proportion of Canadian bachelor degree graduates choosing to undertake PhD studies changes drastically, the numbers of qualified applicants coming forward will certainly decline". There are suggestions that student stipends be increased. We remain unconvinced that stipends need be any higher in engineering than in any other field, but there is one exception and this is that people with substantial professional experience returning to graduate study should be supported at a higher level.

ACAP is inclined to agree with the University of Waterloo's comment, page C-29 in its response to the chemical engineering report, that the best way of attracting Canadian students is a "change in the general atmosphere surrounding doctoral work in engineering in this country and to convince the brightest young Canadian students that there are challenging opportunities for advanced work in Canadian industry". Increased dialogue with industry as well as up-to-date information on jobs available would make the employment picture brighter and more alluring to prospective Canadian graduate students especially if the number of industrial scholarships were increased and more interaction were seen to be taking place between industry and university.

This dialogue with industry is needed to ensure that more Canadians continue in graduate work. If industry indeed has a place for the master's or doctorate in engineering, more must be done to encourage good students to stay in university instead of taking a job after the bachelor's degree. Industry in its hiring policies can encourage this.

The chemical engineering consultants recommend that the universities should endeavour to develop entrepreneurship in students. They feel "this is a quality so badly needed at present in Canada".

It does not seem as though Ontario will overproduce engineering PhDs in the next five years. The question is rather whether there will be enough qualified students. In view of this possible shortage, the following recommendations are made by ACAP.

Recommendation C1

> It is recommended that COU abandon the quota of 450 doctoral student enrolment in 1974-75, and plan on roughly the present enrolment for the next five years, assuming greater interest by Canadian students in engineering graduate work. If this interest does not materialize, the enrolment will undoubtedly drop. In any case, it is recommended that CODE be asked to report annually to COU on enrolment and employment opportunities.

Recommendation C2

It is recommended that steps be taken to inform potential candidates of the value of a PhD in many phases of government and industry, not only in research and development. The universities, individually and collectively, through agencies such as CODE, should discuss with the industrial and governmental employers steps to be taken jointly in order to overcome the shortage of Canadian students.

Recommendation C3

It is recommended that the universities maintain the situation where Canadians and landed immigrants constitute at least 70% of the doctoral enrolment in any programme, at any one time, even though the number of landed immigrants may decrease.

Recommendation C4

It is recommended that the universities, the provincial government, and granting agencies consider the remarks of the consultants and examine the extent to which the limit to student income deters Canadians from entering graduate work. Means of supplementing the income of professionally experienced students should be examined; increased contacts between faculty and industry could lead to increased industrial support.

Admissions

ACAP does not support the view held by the electrical engineering consultants, namely that admitted doctoral candidates should have first class standing and proven research ability. Many students who graduate with high second class honours have become excellent research engineers. The usual minimum standard of the better departments is a high B and all the consultants agree that high standards of admissions prevail generally.

Recommendation C5

It is recommended that each Discipline Group monitor annually the admissions experience of each programme (post facto) and report on the quality of the admitted students to ACAP for transmission to COU.

CODE agrees with ACAP on the annual post facto analysis of admission practices (page H-3). The chemical engineering consultants have suggested "that should it be found that students have been accepted who, in the opinion of the committee, do not fulfill the minimum requirements, the committee advise COU that a recommendation be made to the requisite authority suggesting no BIU be awarded for that student". ACAP does not feel this to be necessary at the present since regular reporting by the Discipline Group should exert considerable pressure if an institution

repeatedly admits students of a low standard.

Undergraduate-Graduate Relationship

Some consultants assert that each department should provide all levels of study: bachelor's, master's and doctoral. Some go so far as to say that a doctoral programme in each department is essential. CODE, on the other hand, feels that what is important for a good undergraduate programme is research and professional activity by the faculty, and that this can be carried forward without graduate students, although at present the research activity is most easily carried on through graduate programmes (page H-3). ACAP agrees with the position stated by CODE and indeed applies it to all subjects, not only engineering, but with the comment that in many fields it is not difficult for a professor to be active in research without having graduate students. We would point out that the other position would imply that no department should exist unless it can operate an effective doctoral programme, a view which we find impossible to accept. The absence of sufficient research and professional activity by professors would raise questions about the quality of a department and hence of its undergraduate offerings, whether or not it offered doctoral work.

Thesis Quality

Recommendation C6

> It is recommended that all doctoral thesis examining committees should have an examiner external to the university.

Since some of the consultants have made reference to the make-up of examining committees ACAP would wish to endorse this practice of including an external examiner.

Critical Size

We agree with CODE that there must be sufficient range of interaction for the student and that the judgement as to the presence of this interaction must include consideration of the involvement of persons outside the student's department and should include post-doctoral fellows and research associates as well as students. Although these planning assessments were vertical, as CODE suggests, each department was asked to state the extent of this interaction in its university. We agree that there is no *a priori* reason why a small school cannot provide as satisfactory an environment as can a large school. The question is not one of principle, but one of fact: does university A in fact provide the requisite environment for interaction for the average student in its department X?

Most of the consultants considered this question carefully and made specific comments but others provide no evidence that they examined the matter in

any of the universities. While most agree that successful programmes can exist in small as well as large departments, the consultants still expect a wide range of courses to be offered. This in turn requires a certain number of students to make the courses economically feasible and academically stimulating.

Mobility of Students

The chemical engineering consultants are concerned about the lack of mobility of engineering students. They do not consider it a good educational experience to study for all three degrees, the bachelor's, the master's and the doctorate, at the same university. Such a programme leads to inbreeding and sameness and precludes any chance for the student to come in contact with different faculty, students, milieu and methods.

One sometimes hears a professor accept this in theory, but then say that in practice the student must not be prevented from going to the university of his choice. That view appears to us to be correct, provided the student's choice is made on sound academic grounds, based on good information of the opportunities that are available to him, and taking account, of course, of the undesirable aspects of remaining in one university.

Recommendation C7

> It is recommended that each Discipline Group and CODE develop proposals for making information on graduate work in all Ontario universities readily available to the engineering students, in some collective way and inform ACAP of the action taken. Each Discipline Group should report annually on the university last attended by the graduate students in each department.

Part-time Programmes

In 1972-73, 18% of the doctoral students studying engineering were doing so on a part-time basis. 65% of these students were Canadians and another 32.5% were landed immigrants. It would appear that these part-time programmes are being used by the profession to upgrade the skills and knowledge of its practising engineers.

The consultants seem divided on the issue of part-time programmes, some saying "such undertakings should be rarely encouraged" and others, "full encouragement should be given to part-time doctoral programmes." ACAP feels that there is a place for the part-time programme and that careful attention should be devoted to designing part-time programmes, bearing in mind the strengths of the departments. One of the dangers sometimes noted is that students become involved, under a part-time supervisor, in a project in an area in which the full-time staff has limited expertise; this is not recommended.

Recommendation C8

It is recommended that at the present any part-time or non-resident doctoral work should be by individual arrangement and that experimentation in this type of programme be encouraged. It is also recommended that the research topic of the student accepted on a part-time basis be in a field in which the professors in the department have expertise. It is recommended that OCGS examine existing university guidelines in this area.

Cooperation

One of the main points that all the consultants agree upon is the need for increased cooperation both within and between universities. The chemical engineering consultants found a need for increased interaction between the engineers and the pure science faculties. Some of the other consultants felt the need for more communication and cooperation between the universities and industry and government. Lastly, more effective use could be made of the resources in the province if the universities themselves joined together in some form of cooperative endeavour. CODE endorses this last point quite strongly in its response, page H-4. Sharing of equipment, discipline meetings and an interchange of credits for graduate courses are a few of the methods listed by CODE that are to be encouraged on the way to making this cooperation a meaningful and workable venture. ACAP concurs with the statements made by the consultants and CODE and strongly supports their implementation.

ACAP intends to request that each Discipline Group report regularly to ACAP on interuniversity cooperative arrangements.

Faculty

Two sets of consultants found enough disquieting evidence in the engineering faculties of the province to suggest that the requirements for a faculty member, eligible to supervise graduate students, should be reviewed and enforced. ACAP takes no position on whether or not there should be a separate Graduate Faculty, but there must be a mechanism to ensure that only those faculty with proven research ability and productivity supervise graduate students.

Since this concern has been mentioned in other assessments, ACAP feels it is time that OCGS conduct a review of this area.

Time to Reach Degree

The electrical engineering consultants were concerned about the length of time taken to obtain the PhD. As they pointed out, the average student at one university took 13-20 months longer to complete his doctorate than his counterpart at another university. As a whole, they found the average time of study to be excessive.

Recommendation C9

It is recommended that the universities report to ACAP (for OCGS) each year on the time taken by each graduating student to complete his doctoral studies.

IV. UNIVERSITY RECOMMENDATIONS

Engineering was split into five separate assessments, one for each of the five traditional fields of engineering. Two universities, Western Ontario and Windsor, do not administer their doctoral engineering work along these lines but rather on an interdisciplinary basis that cuts horizontally across engineering. For this reason, these two universities are being dealt with separately and not as part of the more standard approach evident in the five assessment reports. Similarly, Guelph also is included in this section.

University of Western Ontario

The University of Western Ontario began to offer doctoral work in engineering in 1965. Since then, twenty PhDs in Engineering Science have been granted. From the beginning effort has been made to emphasise its interdisciplinary nature and there has been a limited number of areas in which the student may do his graduate training. At no point has a doctoral degree been given in the so called traditional fields of engineering.

There are seven main research areas in which a student may obtain a PhD in Engineering Science. They are 1. Geotechnical 2. Boundary Layer Wind Tunnel 3. Chemical and Biochemical Process Development and Design 4. Material Science 5. Systems 6. Applied Thermodynamics and 7. Applied Electrostatics. Environmental engineering aspects can be studied in all these research areas except Material Science.

Western's response to the collective engineering picture gives the 1973-74 enrolment as 29 F.T. and 15 P.T. doctoral students. In the additional data given to ACAP, 18 of the 37 current students' programme of study outlined were in the chemical engineering field, 8 were civil, 5 mechanical, and 3 each in electrical and material science.

The chemical engineering consultants have provided evidence of that programme's being of good quality. The systems research area depends heavily on chemical engineering. ACAP, therefore, concludes that the research areas Chemical and Biochemical Process Development and Design, and Systems are of satisfactory quality.

The metallurgical engineering consultants have recommended that the Material Science programme become a part of an interdisciplinary programme rather than an exclusively material science one. This was in part based on the fact that the group is small and spends most of its time teaching at the undergraduate level. They are "carrying a large programme for a group which is subcritical in size." From the additional material supplied by Western, there is little evidence of interdisciplinary activity for students who might be doing research in this area. ACAP concludes that this area should not be operating at the doctoral level.

The areas of mechanical engineering doctoral research work are subsumed under the main research area, Applied Thermodynamics. The consultants indicate that the doctoral research connected with heavy water is of good quality but they raise very serious questions about the doctoral work in acoustics. They feel this area should be restricted to work at the master's level.

The civil engineering consultants did not make comparative judgements, but from some of the phrases used to describe the Boundary Layer Wind Tunnel Laboratory such as "internationally known", ACAP has no reservations in recommending continuance of doctoral work in this research area, even though it appears to have little interaction with other groups. The civil engineering consultants told us nothing about the Geotechnical area and we, therefore, had difficulty in recommending a position to be taken with regard to this field.

The last research area, Applied Electrostatics, is the most difficult to assess. The electrical engineering consultants have recommended discontinuance of the doctoral programme. They feel the students are getting too narrow a training in electrical engineering. We observe, however, that the students are not considered to be studying for a PhD in electrical engineering, but rather for a general degree in engineering science. Although there are only a few faculty members in this area, they are internationally known. The main problem would, therefore, seem to be the extent to which the doctoral training in this area is of an interdisciplinary nature. From the data available to ACAP, we are unsure.

In the course of discussions with representatives of the University of Western Ontario, it became clear that the Faculty is involved in a thorough re-examination of its doctoral programme. It is committed to the concept of an engineering science PhD but is reconsidering the appropriate areas of research. While it is not entirely accepted by ACAP that all the activity is noticeably different from that in engineering departments elsewhere, we nevertheless believe that this intention of the Faculty should be encouraged. A corollary is that it must be very careful about the research areas in which it accepts PhD candidates; we have already commented on these and note the standard of quality seems variable.

These considerations have led us to formulate the following recommendation.

Recommendation C10

> It is recommended that the University of Western Ontario continue its examination of its PhD programme in engineering science, and put forward the resulting programme for appraisal, in particular delineating carefully the areas of research in which it feels it appropriate to accept students. In case a favourable appraisal is not obtained by October, 1976, admission of new students should then be suspended.

University of Windsor

Early in 1971, the Faculty of Applied Science at the University of Windsor began to examine the structure of graduate programmes within the Faculty in order to improve their operation, avoid needless and costly duplication of graduate course offerings and to attempt to create a greater cross-fertilization of research by involving faculty members from different engineering departments in various facets of a larger research plan. This examination led to the recommendation that Graduate Studies be operated on a divisional basis, with the seven undergraduate departments being consolidated under three graduate divisions, namely Engineering Process Design, Structures and Systems. The three divisions would each elect a chairman who would decide on course offerings and enrolment levels. The three chairmen, one elected member from each division, one graduate student and the Dean of Applied Science form a Coordinating Committee to oversee and coordinate the wishes of the Divisions. This plan was approved in Spring 1972 and is now being implemented.

Some of the traditional departments such as chemical and electrical fall completely in one division. All the rest are split between two as can be seen in the attached Table 1.

There are nine identifiable research areas, each of which have participating faculty from at least two of the old departments and these nine areas are in turn divided fairly equally among the three divisions.

The degrees awarded will retain the old titles, for example, a PhD in Chemical Engineering, but the interaction of the individual student with others in the Faculty will be greatly enhanced. Depending on his research topic, the student might take as many as half his courses from professors in other 'departments'.

The consultants' comments concerning Windsor vary, but a number of their reports imply some doubt or uncertainty concerning the relevant departmental programme, either with respect to the situation at the time of their visit, or in connection with its future direction. The chemical engineering consultants suggest that Windsor be reviewed in greater depth. The metallurgical engineering consultants recommend the integration of engineering materials faculty in the new divisional system. The mechanical engineering consultants call for more emphasis on master's work. In the case of electrical engineering the consultants indicate that good work is now being done in doctoral education in two fields, agree with the present plans for no significant growth in enrolment and for no expansion of fields, and go on to recommend a review after five years.

In view of these considerations ACAP feels the University of Windsor should be given time to produce a viable interdisciplinary system of doctoral engineering studies before that system is brought forward for appraisal. This appraisal would determine the level of quality in the new divisional system and whether or not significant interaction has been achieved between the staff and students of the various departments.

Table I

Organization of Engineering Doctoral Work at the University of Windsor

a. % of Department Involvement in each Division

Department	Engineering Process Design	Structures	Systems
Chemical	100%		
Civil	40%	60%	
Electrical			100%
Engineering Materials	50%	50%	
Industrial	10%		90%
Mechanical	60%	40%	

b. Departmental Research Interests

Department \ Research Interests	Structures	Electric Power	Thermofluids	Systems and Signals	Human Factors	Mechanical Metallurgy	Physical Metallurgy	Water and Air Quality	Vibration and Noise
Chemical			x					x	
Civil	x		x			x		x	x
Electrical		x		x					
Engineering Materials	x		x			x	x		
Industrial				x	x	x		x	x
Mechanical	x		x	x	x	x			x

Recommendation C11

It is recommended that the University of Windsor continue the reorganization of its doctoral work in engineering and submit all programmes (presumably these will be the three divisional programmes which are replacing the departmental programmes), for appraisal when the new system has been in operation sufficiently long to permit a valid appraisal. Enrolment of new students should cease after October, 1977 if a favourable appraisal has not been obtained by that date.

University of Guelph

The University of Guelph has for sometime offered an interdepartmental PhD programme in Hydrology in which its Engineering School plays a part. It also plans to develop doctoral work in agricultural engineering, which it already offers at the master's level. There are no other programmes in agricultural engineering in the province.

The matter of the interdepartmental programme would appear not to be central to this assessment. It would not be inappropriate for the Civil Engineering Discipline Group to keep this programme in mind when carrying out the study called for in Recommendation C19. Nevertheless, it seems unnecessary to await the Discipline Group report to make the recommendation which follows.*

From the planning viewpoint, there seems no reason to do other than accept the University's intention to begin doctoral work in agricultural engineering, whenever it feels the time is ripe and the proposal has passed appraisal.

Recommendation C12

It is recommended that the involvement of the School of Engineering in the hydrology doctoral programme at the University of Guelph continue and that the University begin doctoral work in agricultural engineering at a time in accordance with the University's plans, subject to normal appraisal procedures.

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* It may be noted that COU did not accept Recommendation C19.

V. CHEMICAL ENGINEERING

This section of the ACAP report will deal with the recommendations found in the chemical engineering consultants' report. There will be no reference made to Western or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C13

> It is recommended that the departments take note of the consultants' recommendation 10 to group research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for students.

Recommendation C14

> It is recommended that McMaster University continue its doctoral work in chemical engineering according to its plans.

McMaster specializes in process simulation, waste-water treatment, polymer engineering, chemical reaction engineering and catalysis, and transport and separation processes, with stronger emphasis on the first two areas. The consultants feel that McMaster's goals for the future are "realistic" and appear to be "achievable and productive".

Recommendation C15

> It is recommended that the University of Ottawa continue its doctoral programme in chemical engineering according to its plans.

The University of Ottawa specializes in three main areas including thermodynamics and transport properties; kinetics, catalysis and reactor engineering; and transport processes. There has recently been a shift towards a greater environmental emphasis. The consultants encouraged Ottawa to keep up with changes in the areas of research and graduate teaching and move into these new areas whenever possible.

Recommendation C16

> It is recommended that Queen's University reevaluate its doctoral programme in chemical engineering in the light of comments made by the consultants concerning research activity of the faculty, the grouping of research areas, the awareness of new trends in the discipline, and the mobility of its bachelor's graduates, and submit the programme for appraisal at the time that the University considers appropriate. If a favourable appraisal has not been received by October 1976, enrolment of new students should be suspended at that date.

Queen's University specializes in the following five doctoral research areas: biochemical and environment engineering, chemical kinetics and reactor design, process control and simulation, thermodynamics, and transport phenomena. These areas cover most of chemical engineering making a rather uniform distribution of effort. The publication records of only two professors are very good, all the rest being average or low. This raises questions as to the activities of the faculty since their connections with professional and scientific societies can be described as "only mildly active". The consultants feel alarm at the number of Queen's bachelor's graduates who undertake graduate work at the same institution.

On the optimistic side, the consultants note that "the very excellent development planning and programme forecasting suggests that the department's goals and future research activities will be relevant and responsive to the prevailing needs of the province".

ACAP suggests that Queen's might consider strengthening its present faculty, or alternatively, it might consider consolidating its existing wide scope of research areas. As to inbreeding of students, ACAP draws Queen's attention to Recommendation C7.

Recommendation C17

> It is recommended that the University of Toronto continue its doctoral programme in chemical engineering according to its plans, paying particular attention to Recommendation C7 regarding mobility of its graduates and to Recommendation C13 concerning grouping of research areas. It is recommended that the University of Toronto report to COU through ACAP by June, 1975 on action taken in regard to this Recommendation.

The University of Toronto lists eight areas of specialization, all of which show a rather uniform distribution of faculty effort. The exception is a marked emphasis on applied chemistry. The consultants would like to see an effort to group the staff in given areas of research instead of the present policy of allowing a staff member "to select his own path". The consultants did not find Toronto's statement on its plans particularly helpful and they offered no comment on it, other than to say that "it is doubtful whether any increase above the present enrolment would be beneficial to these new students or to the student body as a whole". The University of Toronto should also encourage mobility of its graduates to the benefit of other departments and of the students alike.

Recommendation C18

> It is recommended that the University of Waterloo continue its doctoral programme in chemical engineering according to its plans.

The University of Waterloo has grouped its research activity into five areas including biochemical and food engineering, extractive and process metallurgy, polymer science and engineering, mathematical analysis and control, and transport processes and kinetics. The scope is wide, covering a large part of chemical engineering but, there are defined groups to coordinate the programmes. Although the consultants considered the statement of goals and objectives "less positive and definitive" than others, they were pleased to note Waterloo's intention "to ensure research activities by the use of more post-doctoral fellows and hired research assistants (non-degree candidates) if this should become necessary".

VI. CIVIL ENGINEERING

The report of the civil engineering consultants contains a number of important recommendations of a general character.

Their discussion of the manpower situation supports our Recommendation C1. They suggest that it would be wise to expect rather fewer students than the totality of the stated university plans. Considering the uncertainty of the manpower analysis and the size of the numbers involved, ACAP does not feel it desirable to formulate any recommendations about individual enrolment. ACAP does advise each university to consider the likelihood that the doctoral enrolment in civil engineering may fall still further unless the fraction of Canadian students increases substantially from its present level of about 25%.

Their comments that the "study of a civil engineering speciality in depth necessitates increasingly...some graduate work", reinforces our Recommendation C2 concerning publicizing the value of graduate work.

They argue for more part-time work and closer liaison with industrial and governmental laboratories. Recommendations C2 and C8 touch on this point.

The consultants on pages A-18 and A-35 express their concern that students tend to remain for graduate study at their undergraduate universities, often being unaware of offerings elsewhere. We make recommendations on this problem in Recommendation C7.

The consultants perceive a need for "more consistent requirements of acceptance....between universities". Although we do not recommend the particular remedy they suggest we do make Recommendation C4 in this connection.

On matters specific to civil engineering, the consultants stress the need for more emphasis on fields other than structures. They call for less stress on "traditional areas, particularly structural engineering, and more stress on multidisciplinary education, environmental engineering, and transportation". They suggest that "change of programme emphasis in civil engineering (will) lead to some growth in faculty when generally universities are expecting a fairly static period". On pages A-49 and A-50, they quantify this shift by asking for a 20% reduction in doctoral enrolment in structures (i.e. a drop of about 15 students) together with a corresponding increase, roughly equally in transportation and water resources. Perhaps rather surprisingly they then suggest that no university should offer a new field at the doctoral level. (On page A-52 they also suggest that no university reduce "the range of its doctoral programmes" but on page A-51 they add "unless that university desires otherwise".)

The consequence of this stance, based on pages A-25 to A-29, is summarized in Table 2.

Table 2

CIVIL ENGINEERING

Possible Consequences of the Consultants' Recommendations on Enrolment and Field Emphasis

niversities	Fields				Order of Magnitude of Enrolment
	Geo-technical	Structures	Water Resources	Transportation	
nrleton	S	R	-	I	6
cMaster	-	S	I	-	10
ttawa	S	R	I	-	17
ueen's	S	R	-	-	8
oronto	S	R	I	I	25
aterloo	S	S	I	I	30

LEGEND: R - reduce enrolment
S - static enrolment
I - increase enrolment

NOTE: Guelph, Western Ontario and Windsor are not included in the chart as they are dealt with elsewhere. (See section on University Recommendations.)

There are difficulties in accepting these recommendations. For example, if one asks what the shifts of enrolment from structures would be, to total around 15, one comes up with something like: Carleton 2, McMaster 0, Ottawa 3, Queen's 2, Toronto 4, Waterloo 4. Looking then at transportation one finds doctoral programmes at Carleton, Toronto, and Waterloo which might increase by 2 or 3 at each place. One has to ask if this is the best way to develop more high quality doctoral work. Would it be a better strategy to encourage Carleton, for example, to build a somewhat larger group than 3 or 4 students? There is another concern. Are all the transportation groups of equal promise as places to do doctoral work? If not, should some be strengthened more than others? If we really believe in penny-packet enrolments, could a fourth university perhaps enter this field? The consultants' report provides no satisfactory discussion of these questions to justify its proposals.

Equally unsatisfactory, and perhaps more basically disturbing, is the consultants' failure to give any discussion whatsoever (with three small exceptions) of the facts and reasoning which led them to conclude that all existing programmes are satisfactory. This may be so, but the rationale is far from clear. As the appended correspondence (Appendix 1 to this section) shows, the consultants decline to discharge their terms of reference, in particular C3c and the paragraph following C3d. (See Appendix D).

In particular, although the matter of critical academic enrolment size is discussed in generally acceptable terms, in that the proposition is stated that there is no a priori reason to assume a small school cannot provide as satisfactory an environment for a PhD student as a big school, the consultants neither state the characteristics of such an environment nor do they make any effort to show that it exists in the several small programmes they examined. Although it is no doubt possible to make the justification in several cases, nevertheless a question must still loom unsettled as to the academic strength (from the potential students' viewpoint) of several of the programmes, namely Carleton, Guelph, McMaster, and perhaps Ottawa and Queen's. (None has been appraised.) Of course the consultants' report, due to the lack of rationale in it, gives no reason to suppose that the larger departments are necessarily of suitable quality either.

ACAP cannot justify to itself recommending the acceptance of the consultants' plan, calling as it does for static enrolment, small shifts of emphasis in fields, and no new developments in any department. We feel that the question of the best way to develop doctoral work in transportation and water resources must be more carefully canvassed and that whatever the answer be it must be adequately justified. Some evaluation of the quality of the programme in each broad field at each university must be available before we can make any credible recommendation.

ACAP would like, at this point, to draw attention to the Discipline Group's response, Appendix B. The members of the group feel the consultants did not "seize their unique opportunity to make quality judgements" and failed to "address themselves to the question of quality in the planning function

in their conclusions and recommendations." The group thinks that a statement that "documents the sundry strengths and weaknesses, if they exist, could well increase the value to those on whom the responsibility for planning ultimately rests". ACAP therefore makes the following recommendation.

Recommendation C19

> It is recommended that COU recommend the continuance of the embargo on the funding of any new programmes in civil engineering until COU has accepted a Discipline Group report dealing adequately with the future role of each department in respect to the different fields of doctoral research, paying particular attention to the relative strengths and weaknesses of each department and the change in emphasis on fields recommended by the consultants. The report should be submitted to ACAP by December 31, 1974.

We regret that this recommendation is necessary. We note (page A-5) that the Discipline Group had not prepared for the consultants the report called for by the agreed procedure (page D-6). We note also that the consultants state that they "have formed (their) own judgement about the strengths of different civil engineering departments and the areas in which they are likely to be able to attract high quality students" - we regret that the consultants are not willing to share these judgements with the Ontario university community which employed them.

APPENDIX 1

NOVA SCOTIA TECHNICAL COLLEGE
P. O. BOX 1000
HALIFAX, N. S.

CIVIL ENGINEERING

21 February 1974

Professor M.A. Preston
Executive Vice-Chairman
Advisory Committee on Academic
Planning
Council of Ontario Universities
102 Bloor Street West
Toronto M5S 1M8, Ontario

Dear Professor Preston:

Further to our recent telephone conversations, I have now heard from all my colleagues who fully agree with my letter to you of 4 December 1973.

As mentioned in this letter, we did not discuss the question of quality in our Report since none of the civil engineering doctoral programs were found to fall below minimum acceptable standards.

Moreover, we did not feel the need, nor were we required by our terms of reference, to make relative quality judgements regarding the strengths or weaknesses of individual areas or departments, because in our Report we did not recommend any change in the number or the range of doctoral programs offered by any school, including the various areas of specialization of the smaller universities.

Since the civil engineering discipline group, as well as most universities, find our Report on the whole acceptable, we think that little is gained by getting into an area which might be interpreted as an appraisal or accreditation assessment.

Yours sincerely,

G. G. Meyerhof, Head
Dept. of Civil Engineering

lb
c.c. J.L. Boulet
W.W. Eckenfelder
B.V. Martin

NOVA SCOTIA TECHNICAL COLLEGE
P. O. BOX 1000
HALIFAX, N. S.

CIVIL ENGINEERING

4 December 1973

Professor M.A. Preston
Executive Vice-Chairman
Advisory Committee on Academic
Planning
Council of Ontario Universities
102 Bloor Street West
Toronto M5S 1M8, Ontario

Dear Professor Preston:

After returning from the west coast, I found your letter of 29 November and enclosures, which I read with interest.

In reply and following our terms of reference, we had not discussed the question of quality in our report since, in our opinion, none of the civil engineering doctoral programs were found to fall below minimum acceptable standards.

I am looking forward to the comments of my colleagues, in this regard.

Yours sincerely,

G. G. Meyerhof, Head
Dept. of Civil Engineering

lb

c.c. J.L. Boulet
W.W. Eckenfelder
B.V. Martin

ADVISORY COMMITTEE ON ACADEMIC PLANNING
Ontario Council on Graduate Studies

Professor M. A. Preston
Executive Vice-Chairman

COUNCIL OF ONTARIO UNIVERSITIES
102 Bloor Street West, Toronto 181, Ontario
(416) 920-6865

Postal Code: M5S 1M8

November 29, 1973

Mr. B. V. Martin
Prof. G. G. Meyerhof
Prof. W. W. Eckenfelder, Jr.
Dr. J. L. Boulet

Gentlemen:

I am enclosing all the university comments we have received on your planning assessment report and the formal response from the Discipline Group. You will recall that it is intended to publish these statements.

You will see from the comments that there is considerable dissatisfaction in the universities and in the discipline group with your failure to come to terms with your task of giving us your findings on the relative quality of the doctoral work in the different areas of civil engineering in the different departments. We on ACAP have to agree that one of the most important aspects of the terms of reference you undertook is the statement of strengths and weaknesses of departments, and that without it the report lacks credibility. If you are asserting that all fields offered for doctoral work are competently dealt with wherever they are offered, it will follow that civil engineering is a paragon amongst disciplines. Even if true, it does not help the universities to decide which areas to strengthen.

In one of the few specific comments, you do suggest that McMaster should emphasize earthquake engineering. Do you think its work in water resources is strong enough that it should seek to expand or maintain that, or, when you recommend <u>greater</u> emphasis on water resources, do you expect this to be achieved at Ottawa, Toronto, Waterloo and Windsor for example? McMaster (and the others) would like to know. You tell the University of Western Ontario to emphasize boundary layer wind tunnel work; but what about their geotechnique? Since Guelph now has 5 students in its hydrology programme, how can it be exploiting its unique facilities for agricultural engineering if its enrolment becomes 4 to 7? Is it expected to cut back on hydrology? To consider this, it would be necessary to know how valuable Guelph's hydrology work is and how substantial is the potential of its agricultural engineering programme.

I mention these points only as examples of the kind of question on which your adivce would be helpful. The general point is that your judgements of quality by department and by area are important. You recommend that transportation be strengthened; we ask, where? If all the departments say "here", how are decisions about resource allocation to be made without the quality judgements you were expected to give?

....2/

One of the aspects of academic quality has to do with the size of the student enrolment. You will see from the university responses that there is some difference of opinion. The official position of COU, recently adopted, is as follows:

"The quality of graduate programmes is partly dependent on size, and for each programme, depending on how it is designed and its scope, there is a minimum size of enrolment below which quality may suffer. That number cannot be expressed for the discipline as a whole but only for individual programmes depending on their purpose, their resources and their design."

Recommendation 4 on page 52 of your report is not inconsistent with the above statement, but you do not indicate what criteria determine the "satisfactory environment." In ACAP we have identified two areas which we believe should be examined in this connection. One is the opportunity for the students' development through informal intellectual discussion with a peer group with common engineering or scientific interests. This peer group need not consist only of students; it may also include post-doctoral fellows. It need not be confined to one department, but may include students in other departments if there is a real sharing of research interests. The second main area for consideration has, we feel, to do with graduate courses. Assuming that a course with, say, 5 or 6 students who interact is a much more satisfactory experience than one with 1 or 2 students, we see that the desirable enrolment size is a function of course structure. If there were a programme which did not require courses, this second criterion of size would not apply. But if it is felt that students should take a substantial number of courses (as appears to be the case in all the Ontario departments), then the consideration is valid and the situation needs examination.

It appears that some of our departments plan enrolments as small as 6 to 12. It may be that some of these departments, because of specialization, course structure, post-doctoral and master's population and interdepartmental collaboration, offer an academically sound experience for the student, while other departments with the same enrolment may not. Each case needs evaluation separately.

This brings us back again to the desirability of your giving a detailed analysis of each university. We request evaluation of quality by area of study of each department, including an analysis of the kind of intellectual milieu established for a student by the enrolment size.

I hope you realize that we have a problem of reconciling the reports of the consultants on the various engineering disciplines. One report of which there seems to be pretty general approval is that dealing with electrical engineering. Of course not all its details are accepted by everyone, but the style and coverage of the report has not been attacked. I enclose a copy, since it may make clearer what I have been trying to say in this letter.

After you have had a short interval to consider the letter, I shall telephone Professor Meyerhof to discuss the mechanism of your response. We need your assistance.

Yours sincerely,

M. A. Preston

MAP/cew
Enclosures.

VII. ELECTRICAL ENGINEERING

This section of the ACAP report will deal with the recommendations found in the electrical engineering consultants' report. There will be no references to Western Ontario or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C20

> It is recommended that the Discipline Group annually identify those areas of electrical engineering which they consider relevant to the present and future needs of Canada and make their findings available to the granting agencies and various associations of industry in order to stimulate a continuing dialogue with industry.

Other Discipline Groups might also consider this recommendation.

Recommendation C21

> It is recommended that Carleton University continue its doctoral work in electrical engineering according to its plans.

The work in electrical engineering at Carleton is divided into two departments, Electronics and Materials Engineering which includes solid state device electronics, circuits and circuit theory, microwave electronics and electron beam systems and processes and the Systems Engineering programme which concentrates on information systems such as communications and signal processing, decision and control, digital systems design and software engineering. The coverage within these two areas is well integrated, coordinated and appropriate for PhD training. The enrolment increase proposed by Carleton is within the competence and capability of the present staff.

Recommendation C22

> It is recommended that McMaster University continue its doctoral work in electrical engineering according to its plans.

McMaster has outstanding strength in three areas of graduate research and has plans to strengthen a fourth. These are communications and data processing, modelling and design, materials and devices and, lastly, medical electronics. The electrical engineering programme at McMaster is of high quality, with a productive and dynamic faculty.

Recommendation C23

> It is recommended that the University of Ottawa continue to offer a doctoral programme in electrical engineering restricted to theses in digital communication systems and large-scale systems. This limited programme is to be appraised as soon as possible. Enrolment of new students should cease as of December, 1975 if a favourable appraisal has not been obtained.

The department at Ottawa specializes in three areas, communication systems, control and systems, and computer engineering. With a faculty of 11, the consultants felt that they were spread over a rather large area of electrical engineering. A small department with a small number of staff and students can operate an effective doctoral programme only with competent professors, complementary fields of study and an adequate research environment. The consultants recommend discontinuing the programme. ACAP has considered both the consultants' report and the university's comments and has concluded that Ottawa has a contribution to make to graduate electrical engineering study in operating a specialized programme of limited scope and enrolment.

Recommendation C24

> It is recommended that Queen's University continue its programme in electrical engineering concentrating in the communications and systems fields, with occasionally a student in cognate areas of electronics and energy processing. Any proposed substantial developments in these latter two fields would be submitted for appraisal. It is also recommended that the department maintain enrolment at its present level.

The areas of specialization at Queen's are communications, systems, electronics, and energy processing. The consultants state that the work in communications is good but is only fair in systems, and that the Department should not offer a programme in the latter two fields on a regular basis. However, we suggest that an occasional student be allowed to do a thesis in one of these fields. ACAP accepts the consultants' view about enrolment which was made on academic grounds, not for planning reasons.

Recommendation C25

> It is recommended that the University of Toronto continue its doctoral work in electrical engineering according to its plans.

Graduate work at the University of Toronto covers seven areas including communications, computers, control, power devices and systems, solid state electronics, wave sciences, and biomedical electronics. The coverage of these fields is more than adequate and Toronto's "star-studded" faculty are spread over the seven areas indicating significant breadth across the department. The consultants conclude that the Toronto department compares favourably with any of the major institutions in North America.

Recommendation C26

> It is recommended that the University of Waterloo continue its doctoral work in electrical engineering according to its plans.

The University of Waterloo concentrates in five major areas including computers and communications; control, systems and networks; devices, circuits and materials; power engineering; and, antennas and electromagnetic engineering. There are two minor fields, bioengineering and electroacoustics, and these fields should be limited in size to the present level of activity. With Waterloo's highly competent faculty and well-equipped facilities, there is no question that the enrolment level planned by Waterloo can be accommodated.

VIII. MECHANICAL ENGINEERING

There are a number of general recommendations and comments made in the mechanical engineering consultants' report that are aimed at the system as a whole. Recommendations for the individual universities follow this more general section.

The mechanical engineering consultants do not anticipate any oversupply of mechanical engineers. They believe no "artificial edict" is necessary to control the number of PhDs. On the contrary, they suggest the problem will be one of availability of good students. The consultants think that Ontario might, in fact, have a shortage of mechanical engineers.

"Traditional classical" versus "applied" research projects and a shift in emphasis of study are the next problems attacked by the consultants. They feel that the doctoral education of today should shift more towards project and design activity. To this end, they advocate increased dialogue and cooperation with outside agencies such as industry and government. "If we look at the problems before us today in the fields of energy, transportation, or the environment, it is apparent that there are many gaps in the knowledge which should be attacked systematically to provide the basic design data which is essential to advances in engineering and advances generally in technology on the broad front". The consultants also recommend a change in emphasis in fields of study. Some areas of research that need to be developed are listed on page A-14.

The consultants do not condone departments that attempt to be good in all fields. They feel specialization is the key and that "considerable selectivity is required in the choice of a particular area of concentrated effort". This choice of areas of concentration should be left up to the universities. ACAP agrees with this outlook but notes that the initiatives of each department in Ontario are matters for collective consideration and advice. ACAP advises the departments to consider the consultants' suggestions noted in the addendum and asks that they report on progress made after a year of mature consideration. After this time, the Discipline Group, in its normal role, would continue to consider the development of new areas of graduate study and the possible entry into neglected fields in mechanical engineering in Ontario and would make recommendations to ACAP where change is desirable.

Another problem the mechanical engineering consultants addressed was the one of faculty age. Since the Ontario universities have been through an expansionary period in the sixties, a large proportion of the faculty is below 45 years old, consequently lacking something in maturity and industrial experience. The consultants feel that although the retirements in the next several years will be few, the universities should take these opportunities to introduce new blood by appointing faculty with industrial experience.

It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendations

Recommendation C27

It is recommended that Carleton, McMaster and Queen's Universities continue their doctoral programmes in mechanical engineering and during the coming year give careful consideration to the feasibility of a stronger development of foci of interest in the special areas of strengths suggested by the consultants. The Universities are requested to report to COU and OCGS, through ACAP, during the Fall of 1975, on the results of these considerations.

The Mechanical Engineering consultants, in their addendum, give valuable suggestions for focussing research activities in each department. These suggestions appear to be based on both planning grounds and grounds of academic quality, but alternative research foci may not be ruled out. Consequently, ACAP recommends that the three doctoral programmes continue but that each university note the consultants' comments and report on progress in a year's time.

Recommendation C28

It is recommended that, if the University of Ottawa wishes to reactivate a doctoral programme in mechanical engineering, it give careful consideration to allowing some further maturing of the department before applying for appraisal.

The consultants, in their remarks concerning the University of Ottawa, page A-17, recommend that the work in the Mechanical Engineering Department be incorporated in an interdisciplinary programme leading to an undesignated PhD degree. ACAP notes the university response, page C-14, which states that they wish to "reactivate" the doctoral programme, before discussion of this new proposal. We do not at this time make a recommendation on the future form of engineering PhD work at the University of Ottawa. There appear to be no planning reasons why there should not be a programme at Ottawa in mechanical engineering, but the consultants have serious reservations about the suitability of a number of the research projects of the department and about the limited industrial experience of its staff members.

Recommendation C29

It is recommended that the University of Toronto continue its doctoral programmes in mechanical engineering in its Department of Mechanical Engineering and the Department of Aerospace Studies and Engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities of the Department of Mechanical Engineering on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

We draw the attention of the University of Toronto to the consultants' suggestion that the Department of Mechanical Engineering concentrate research on problems of major, national concern. UTIAS should note the consultants' comments on the need for selectivity within the broad spectrum of the expertise of the staff, in such areas as plasma science, low density gas dynamics, subsonic aerodynamics, flight dynamics, shockwave phenomena and noise. The consultants also favour increased interaction with work in related fields on the main campus.

Recommendation C30

> It is recommended that the University of Waterloo continue its doctoral programme in mechanical engineering. ACAP suggests that the University consider the consultants' recommendation of a greater concentration of research activities on major problems of national concern. It is recommended that the University inform COU and OCGS through ACAP, during the Fall of 1975, of any decisions taken.

ACAP notes the consultants' suggestion that the department concentrate in Production and Automation. We also take note of Waterloo's response which lists strengths in other areas. We recommend that Waterloo consider the consultants' idea of developing foci of research interest and report on any action thought desirable.

The University of Western Ontario and the University of Windsor have not been discussed here, since there is no need for any recommendations in addition to those in the section on University Recommendations, page 20.

IX. METALLURGICAL AND MATERIALS ENGINEERING

This section of the ACAP report will deal with the recommendations found in the metallurgical engineering consultants' report. There will be no references to Western Ontario or Windsor since these two universities were mentioned in a previous section. It is important that the consultants' report and the university and discipline group responses be read at the same time as this ACAP report.

Recommendation C31

> It is recommended that the universities take note of the consultants' recommendations 1, 2, 3b and 3c, dealing with the weakness in certain fields of study in the province and that the Discipline Group report to ACAP on any action taken in consequence of these reommendations.

The consultants find it surprising that there is so little effort in the ceramics and glasses fields of study. Even more striking to them is the absence of any work in polymers in the Departments of Metallurgy and Materials Engineering. In their first few recommendations, they consider it very important to rectify these neglected areas and ACAP feels this is a job for the Discipline Group. They also feel it is important to strengthen already existing areas of study and in particular create at least one internationally-known centre of materials science activity.

Recommendation C32

> It is recommended that McMaster University continue its doctoral programmes in materials science and extractive metallurgy, and noting the strength attributed to these programmes by the consultants, make a report in the fall of 1975 on the following suggestions for improvement:
>
> a. recruitment of students with physics and chemistry backgrounds
>
> b. strengthening of the extractive metallurgy faculty
>
> c. collaboration with Toronto

The materials science programme at McMaster is considered by the consultants to be the best programme of this kind in Ontario and probably in Canada. It is the only programme that covers adequately the basic science related to all classes of materials including polymers. The enrolment could be easily doubled without developing the need for any significant increase in resources allocated to the programme, but enrolment, here, is limited as in so many other areas of engineering, by the number of qualified students.

The extractive metallurgy programme, although not as strong as the materials science one, provides very suitable research for the doctoral thesis. The range of the programme is, however, inadequate but cooperation with other McMaster Departments and with the University of Toronto will greatly enhance the operation of this programme.

ACAP suggests that McMaster consider the points put forward by the consultants and that the university report to ACAP on any action taken with regard to these recommendations.

Recommendation C33

> It is recommended that Queen's University continue its doctoral work in physical metallurgy and discontinue the doctoral programme in extractive metallurgy and mineral engineering as it now exists and replace it by an enlarged programme involving professors in other departments as suggested in the consultants' report. This new programme should be appraised and this should be completed by December 31, 1976. If Queen's does not wish to enlarge its programme in extractive metallurgy and mineral engineering, the present programme should be put forward immediately for appraisal, ceasing to enrol new students by June 30, 1975 if a favourable appraisal is not obtained.

The consultants consider the programme in physical metallurgy at Queen's a good, traditional type of programme taught by young and talented faculty. Although it would make a suitable base on which to build a programme in materials engineering, the consultants do not recommend that Queen's do so.

The programme in extractive metallurgy, on the other hand, is not so well off. It is seen by the consultants to be inadequate in its present form, with too small a range of courses, too limited an amount of research activity, and ineffective interactions with other departments and programmes. But the consultants feel it is necessary to strengthen and develop this field, to provide the needed PhD graduates and maintain Queen's part in a history of leadership in Canada in mineral engineering, geology and related fields.

The enlarged programme of extractive metallurgy is envisaged by the consultants to consist of support from the Departments of Metallurgical Engineering, Chemical Engineering, Mining Engineering and Geology. ACAP realizes that cooperation cannot be legislated, but it must have some formal structure in order to make the various professors aware of their part in a cooperative venture and secure the recognition of their departments for the effort devoted to the venture.

Recommendation C34

> It is recommended that the University of Toronto continue its doctoral programmes in its Department of Metallurgy and Materials Science. It is suggested that Toronto give careful consideration to the consultants' recommendations concerning broadening the programmes and it is recommended that the University report to COU through ACAP by September, 1975 on any progress made in this direction.

Toronto has an international reputation for its graduate work in extractive metallurgy. However, the range of courses is limited; this situation could

be improved through cooperation with McMaster. The consultants feel this would provide a good base from which to develop a programme in mineral engineering and extractive metallurgy and they advise the university to do so.

In addition to those who work in extractive metallurgy there is another group of professors in the department who describe their work as physical metallurgy and materials research. These people working with added specialists in polymers and electrical and optical properties of materials would form a group capable of mounting a substantial programme in materials engineering.

Recommendation C35

> It is recommended that the University of Waterloo continue its engineering doctoral work in extractive and process metallurgy and in metallurgical engineering and materials science according to its plans.

Waterloo has no specific programme in materials and does not offer a PhD labelled as metallurgical engineering or any allied field. Instead, students are trained in extractive metallurgy in the Department of Chemical Engineering and there is a group of metallurgists and materials scientists in the Mechanical Engineering department. The consultants felt their effort was of such high quality that if this group were constituted as an administrative unit, they would be the strongest and most comprehensive graduate programme in materials engineering in the province. The consultants recommend setting up a separate administrative structure. However, the unit (all in one department) appears to function well without separate administration and ACAP does not feel that such a structure is imperative. Waterloo will, no doubt, consider the consultants' suggestion.

X. MINING ENGINEERING

Queen's University offers the PhD in mining engineering. This is unique in the province. Although the enrolment is small, the programme appears to fill a distinct need. The University projects no enrolment increase, showing only 4 students in 1977-78.

On the basis of the statement of future plans made by the University, we recommend:

Recommendation C36

> It is recommended that Queen's University continue its doctoral work in mining engineering in accordance with its plans.

XI. INDUSTRIAL ENGINEERING AND SYSTEMS DESIGN

This section of the ACAP report will deal with the recommendations found in the industrial engineering and systems design consultants' report. It will contain recommendations on the Universities of Toronto and Waterloo. ACAP suggests that the University of Windsor take careful note of the recommendations made in this consultants' report but at this time ACAP makes no specific recommendations on doctoral work in industrial engineering at Windsor since it is part of the earlier Recommendation C11.

The general recommendations in this report echo many of those found in the earlier consultants' reports. These consultants' estimates of manpower supply and demand closely follow those made by the other consultants and are discussed more fully in the second part of this ACAP report. Related to this is the need to increase the Canadian content in engineering programmes. Recommendations C1 and C3 refer specifically to these two points.

ACAP notes that the universities do not consider the establishment of a co-ordinating committee to be very important. We hope that talks are normally taking place between the three departments and that they will continue. ACAP feels there is no need to set up a formal Discipline Group to ensure discussions but if those concerned wish to do so it can be arranged.

Again, as in the other consultants' reports there is seen to be a need to circulate information to the student concerning the various programmes in order to ensure he selects the programme best suited to his objectives. This problem has been addressed by Recommendation C7.

ACAP endorses the consultants' recommendations 6,7,8,9 and 11 and does not wish to make any particular comments on these recommendations.

Recommendation C37

> It is recommended that the University of Toronto continue its doctoral work in human factors engineering, management information systems and operations research.

In its response to the consultants' report, the University of Toronto seems in general agreement with the recommendations made concerning its programme. ACAP notes that the Department has already made the appointment suggested in recommendation 3.

As far as future enrolment is concerned, ACAP suggests the university continue to expect approximately the same enrolment as it now enjoys. In accordance with standard appraisal procedures, a shift in fields of specialization to programmes in health systems and energy systems would require referral to the Appraisals Committee to determine whether or not an appraisal is necessary.

A review of the enrolment expectations would be made at that time. For the present, a continued output of 3 or 4 PhDs a year should be expected by the university. This should not be regarded as a quota but rather as the outcome of the present situation of fewer qualified students and falling enrolments. It should be noted that the University of Toronto has maintained a high percentage of Canadians in its industrial engineering programme in comparison to other engineering programmes both in the University of Toronto and elsewhere.

Recommendation C38

> It is recommended that the University of Waterloo continue its doctoral programme in systems design.

ACAP takes note of the response of the University of Waterloo to the consultants' various recommendations concerning the Department's isolation, its "soft" course content and the quality of recent staff appointees. Despite the possibility that enrolments may increase in this field and despite the comments from the University, ACAP considers that Waterloo should give careful attention to the consultants' recommendations for strengthening the programme before increasing the enrolment.

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APPENDIX A

REPORT ON PHD PLANNING ASSESSMENT IN CHEMICAL ENGINEERING IN ONTARIO UNIVERSITIES

Submitted to the

ADVISORY COMMITTEE ON ACADEMIC PLANNING
ONTARIO COUNCIL ON GRADUATE STUDIES
BY THE CHEMICAL ENGINEERING CONSULTANTS

Pierre Grenier, Doyen de la Faculte des Sciences
Laval University, Quebec City, Quebec.

W. Robert Marshall, Dean of the College of Engineering
University of Wisconsin-Madison, Wisconsin.

Leo Yaffe, Macdonald Professor of Chemistry
McGill University, Montreal, Quebec.

October, 1973.

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PREAMBLE

Chemical engineering, although one of the younger of the founding engineering disciplines, has exerted a major beneficial impact on the material well-being of mankind. In contrast to the other engineering disciplines such as civil,mechanical, electrical, etc., chemical engineering is based more broadly on the science of chemistry and equally broadly on the sciences of physics and mathematics. As a consequence, a chemical engineer has a unique element of flexibility or competency because of his knowledge of chemistry and how to apply it on a large scale to effect and control the chemical change of matter. By keeping abreast of advances in chemistry, the chemical engineer is able continually to apply these advances for the benefit of mankind. Prior to the present era of concern for and protection of the environment, chemical engineers contributed principally to industrial and economic growth through the development of new products, and the development of processes for manufacturing these products. Equally important has been the chemical engineer's role in improving and making more efficient existing processes as the fundamental chemical and physical phenomena of these processes became better understood.

To understand the reasons for the success and contributions of chemical engineering certain vitally important facts must be recognized. The continued contributions of chemical engineering to the economic growth of Canada have occurred because research in chemical engineering in the universities has been productive a) in terms of industrially useful research results and b) in terms of the education of students at the PhD level who, because of their education have carried their skills and results of research into industry. It is not difficult to argue, therefore, that an adequate source and a continuing flow of PhDs in chemical engineering is as essential to the future of Canada's development as any of the other natural resources of Canada. Chemical engineering will be a primary tool to help solve many problems of society, some of which will be in the field of energy, recycling of wastes, resource management, product safety, etc.

The proposition that chemical engineers trained at the doctoral level are essential to Canada's future industrial and societal needs seems obvious; it may not be as obvious that excellence in undergraduate engineering education can be maintained only if strong graduate research programmes exist to serve as the fountainheads for the continual flow of new knowledge and theory into curricula and courses. Professional engineering schools whose programmes have broad scientific bases must have PhD level graduate-research components with quality faculty, funds, and facilities.

1. INTRODUCTION

1.1 Origin of Study and List of Departments

This report arises from the general review of PhD programmes in Ontario universities being undertaken by the Advisory Committee on Academic Planning (ACAP) of the Council of Ontario Universities. The report deals with the programmes leading to the PhD in the Chemical Engineering Departments at:-

McMaster University
University of Ottawa
Queen's University
University of Toronto
University of Waterloo
University of Western Ontario
University of Windsor

This report looks at the scope, nature and quality of the PhD programme, the type of student it attracts and the employment prospects on graduation. Recommendations are made regarding the future of these programmes in view of the concurrent discussions regarding the place and need for such programmes in Ontario higher education.

The consultants first assembled in Toronto at the end of May, 1973, for preliminary briefing, initial studies and conversations with the discipline group, composed of the seven department chairmen. On-site visits to the various universities took place in July, August and early September. The draft report was assembled and completed before November 1st and submitted to Professor M.A. Preston, Executive Vice-Chairman of ACAP, for transmission to members of the discipline group for oral response which took place at a joint meeting with the consultants on November 9. The final report was submitted on the same day.

1.2 Consultants

The team of consultants consisted of:

Pierre Grenier, Doyen de la Faculté des Sciences, Laval University, Quebec City, Quebec.
W. Robert Marshall, Dean of the College of Engineering, University of Wisconsin-Madison, Wisconsin.
Leo Yaffe, Macdonald Professor of Chemistry, McGill University, Montreal, Quebec.

Detailed curricula vitae can be found in the Appendix.

1.3 Modus Operandi for Visits

The following Departments of Chemical Engineering were visited by all of the consultants for the Period of time listed:

McMaster University	1½ days
University of Ottawa	1½ "
Queen's University	1½ "
University of Toronto	2 "
University of Waterloo	1½ "
University of Western Ontario	2 "
University of Windsor	1 "

While the order of events varied from university to university, yet a typical visit included the following:

(1) Discussion with the chairman on departmental policies regarding graduate work.

(2) Discussion with departmental officers concerned with graduate student admission policies and procedures.

(3) Discussion with staff members regarding their individual research interests as they concern graduate students.

(4) Visit to research laboratories and inspection of facilities.

(5) Visit to computer, workshops and library facilities.

(6) Informal discussions with PhD students (in absence of staff members, with one exception).

(7) Discussion with Dean of Engineering, Dean of Graduate Studies (or Vice-President i/c Research or Provost, etc.).

Each department supplied to the consultants, through ACAP, the following data:

(a) 5-Year Plan of the Department (approved by appropriate officer in the university) for PhD work.

(b) List of present faculty and detailed curricula vitae, as of November, 1972.

(c) Numbers of faculty, master's students, PhD students, and post-doctoral fellows (1968-69 to 1972-73).

(d) Degrees held by faculty and country obtained.

(e) Distribution of faculty by age.

(f) NRC, DRB, MRC and other operating grants.

(g) Number of PhD theses supervised by individual faculty.

(h) Detailed description of research interests of faculty.

(i) Numbers of undergraduate degrees awarded from 1967-68 to 1971-72.

(j) Country where first degree was obtained for master's and PhD students (1968-69 to 1972-73).

(k) Curricula vitae of some PhD students.

(l) Sources of financial support for graduate students.

(m) Length of time for a student to obtain a PhD degree, 1969-70 to 1972-73.

(n) Employment survey of PhDs, 1968-69 to 1972-73.

(o) Major departmental equipment (costing more than $5,000).

(p) Many reprints of research publications.

(q) On request, details of graduate student applications (numbers, origin, initial rejections, numbers of application forms sent and returned, acceptances, no-shows, etc.).

(r) On request, evaluations of theses by external examiners.

1.4 Acknowledgments

The consultants gratefully acknowledge the invaluable assistance rendered by Miss Susan Cale and Professor M.A. Preston. The former supplied the invaluable documentation listed above. Professor Preston briefed the consultants and was always readily available for consultation. In addition the consultants appreciated the help given by the rest of the COU staff.

The consultants also acknowledge with gratitude the cordial reception given to them in all of the departments visited. A great expenditure of time and energy on their part was obviously necessary, prior to and during the visit. This made the visits very profitable and for this the consultants are grateful.

2. SUMMARY OF GENERAL EVALUATIONS

2.1 Scope of Chemical Engineering

Chemical engineering has generally been described as the application of the physical sciences to produce, economically for the benefit of mankind, materials and products from processes involving chemical or physico-chemical change. However, the scope of chemical engineering has broadened during the past decade as a result of the rapidly growing problems of society and hence the chemical engineer in the next decade not only must apply his knowledge of the natural sciences but must utilize knowledge of the social and behavioural sciences. Thus, chemical engineering is entering a new realm wherein manifold societal values coupled with a limited range of presently-known technically feasible alternatives result in the decision-making processes becoming exceedingly complex. Because in meeting social demands present technology may not be sufficiently advanced, the need for research to develop new technical alternatives is clearly apparent.

Only by understanding as completely as possible the scope of chemical engineering, both now and in the future, can a process or a programme for the education of chemical engineers be wisely developed. Hence, it is essential to evaluate existing and planned programmes of education, especially those at the PhD level, in terms of a rational frame of reference.

2.2 Objectives of the PhD Programme in Chemical Engineering

Inasmuch as the objectives of the programme are concerned, the key concept is certainly a form of "advanced training in problem-solving" in a constantly widening field which was traditionally limited to the chemical and process industries but now encompasses important aspects of the environment, of energy conservation, of resource management and development, etc. This concept is universally accepted, as a valid objective either implicitly or explicitly in all the Ontario departments.

The method by which this is carried on is really a modern form of apprenticeship in which the interaction between the student and his supervisor is the element of paramount importance. This has to be complemented however by acquisition of deeper knowledge in some specialty through formal teaching and by interaction with an intellectually stimulating group of fellow students and faculty members.

Some of the essential components of a frame of reference for a PhD programme evaluation should then be:

(a) PhD research should have a chemical engineering character and objective.

(b) The research should have not only immediate but also long-range relevance to the extent the latter can be predicted.

(c) All modern tools for significant research should be available. They include modern computers, libraries, shops, and other related services.

(d) Viable relationships should exist among the research programmes and their goals, the faculty, the students and employers or customers for the PhD chemical engineer.

2.3 Chemical Engineering vs Chemical Engineering Science

In contrast to the situation in the various disciplines of pure science, where research associated with doctoral studies is almost invariably of a fundamental nature, additional research avenues are open to chemical engineering graduate students because of the very nature of engineering whose general purpose is 'to make' rather than 'to find'. Whatever these avenues are called - applied or mission-oriented research, development or design - they represent hard-to-define and overlapping realities.

During the last quarter of a century, a body of knowledge, specific to chemical engineering, has developed in areas such as transport phenomena, reactor design, modelling and simulation, etc; these areas are fundamental and can be most appropriately classified as chemical engineering science. Research has been and continues to be needed in many of these areas to fill to gap between existing knowledge and applications.

In Ontario as well as in the rest of North America, chemical engineering faculty have deployed by far the largest part of their research activities in chemical engineering science. This is not surprising, considering the policies of the most important granting agencies serving the universities and the emphasis put on scholarly work which will lead to the diffusion of knowledge through publications in scientific journals as a requirement to a successful university career.

However, such research orientation plus university policies have caused a serious neglect of the more 'engineering' aspects of chemical engineering; e.g., the production of materials, design of processes and equipment, synthesis of systems, the improvement of the quality, reliability and efficiency of processes, safety, etc.

The advent of new granting programmes, mostly of the mission-oriented type, should help to restore a more suitable balance between fundamental engineering research and research concerned with application and design in the universities. In the Ontario departments of chemical engineering, trends in this direction are already clearly evident. These trends should be encouraged by government, industry and supported by the university.

2.4 Coverage of Field by Ontario Universities

In general, both research and the doctoral programme in chemical engineering are well developed in Ontario.

Although there are now in all departments efforts to group researchers into definite areas, the present situation is the result mostly of the

individuals' initiative. According to the C.S.ChE method of classifying research areas, (see Section 6.14) the field of chemical engineering, at least as far as fundamental research is concerned, is very well covered in Ontario and, to a variable extent, in the majority of the individual universities themselves.

If a decision were made to coordinate research efforts by assigning selected areas to selected universities, this would mean major shifts of emphasis for many faculty in the majority of departments and would disrupt the research activity rather seriously, at least for the transition period.

There is room in the Ontario system at the present for more activity in applied research and development.

2.5 The Job Market and Need for Programmes

One of the most precarious and hazardous endeavors of surveys and forecasts is the prediction of engineering manpower needs. Examples of inaccurate and misleading forecasts are numerous, and it is difficult to assess the damage to national needs and economies created by such erroneous forecasts. Probably the most damaging results from erroneous manpower surveys are on the careers of young people who believe implicitly in the accuracy of the forecasts and proceed to make career decisions which may not be their preferred choice. Even at this period in time, students are witnessing a complete reversal of the predictions of the past three years that there will be a scarcity of jobs for engineers in the next decade. Thus as we observe, as a result of these forecasts, dramatic reductions in engineering enrolments, at the same time we also observe that, in fact, a serious shortage of engineers can occur during the next five years.

Survey specialists have yet to develop reliable forecasting techniques. They must improve their abilities to recognize that new engineering and technological developments and societal demands have, and will continue to make forecasts of manpower needs highly uncertain. We need only cite as examples the developing engineering career opportunities in medicine, in environmental control and regulation, and in safety, risk and insurance, to underscore the uncertainties in forecasting the needs for professionally educated manpower.

Accordingly, the evaluations of the PhD programmes in chemical engineering by the ACAP consultants were only mildly concerned with the question of the job market for PhDs in chemical engineering. A general assumption was held that the PhD chemical engineer by virtue of his education possesses such a powerful potential for career opportunities in a variety of fields that the question of the job market was not too relevant to the assessment.

2.6 Role of Chemistry Departments

The essential differences between chemistry and chemical engineering are well recognized. It surely is a truism however that chemistry must play

a unique role vis-à-vis its engineering counterpart. The importance of a good chemistry department in a university which expects a good chemical engineering department cannot be over-stressed. In addition good interaction between such departments is essential. It is distressing to see how few such scholarly interactions exist, as was found during the tour of the Ontario universities.

Some chemistry departments are excellent by international standards. Nevertheless very little attempt is made by the chemical engineers (and vice-versa) to avail themselves of these talents, even though in many of the chemical engineering departments visited, the research work not only is indistinguishable from that done in chemistry departments, but is often published in chemistry journals!

Good interaction was however, in general, found at the teaching level. Most of the basic chemistry courses are taught by the chemistry departments. In some cases concern was expressed that courses are not geared to engineers, but dissatisfaction appeared to be at a low level. The notable exception is at the University of Toronto where the interaction between these departments is so small that, apparently for historical reasons, virtually all the basic chemistry courses taught to engineers are taught by the Department of Chemical Engineering and Applied Chemistry. Although many teachers of these courses were initially trained as chemists, they have long since ceased to rub shoulders with fellow-chemists. This seems to be a rather serious academic problem at Toronto, especially since a very high percentage of the PhD students obtained their first degree at Toronto. Surely it would be salutary to have chemistry taught to the students from several view-points! The situation can be exemplified by the fact that even those engineering undergraduate students who change their final goal to medicine or dentistry are taught auxiliary organic chemistry not by an organic chemist but by a chemist in the Department of Chemical Engineering and Applied Chemistry.

2.7 Employment Prospects

Detailed lists of type of employer and geographical location of positions taken by PhD graduates as their first job after graduation since 1969 are shown in Tables x.10 (where x refers to the code number allocated to the university department). With very few exceptions positions were available for these PhD students on graduation. The survey of the situation as of January 1, 1972, showed little change in the positions occupied by these chemical engineers.

Thus, at the present rate of graduation of PhD students, job opportunities should not be an influencing factor in any decision.

3. RECOMMENDATIONS

On the basis of their findings and conclusions the consultants recommend:

1. That, if indeed a suitable basis for planning the development of PhD programmes in Ontario universities were found, such planning should be done separately for the various individual branches of engineering (e.g. chemical, civil, etc.) rather than for engineering as a whole;

2. That, considering the length of time required to establish a high-quality PhD programme, no short-term considerations should be involved in any planning;

3. That the PhD programme be regarded as an integral part of the total educational process in chemical engineering, and by its presence strongly influencing programmes at other levels in a given university;

4. That no university having a bachelor's and a master's programme be prevented permanently from offering a doctoral programme;

5. That because no evidence of major overproduction of PhDs in chemical engineering in Ontario exists, the total population of PhD students in the province as forecast and desired by the departments not be reduced significantly during the next five years;

6. That, considering the decreasing numbers of Canadians registering in PhD programmes in chemical engineering, appropriate steps be taken to inform:

   1) potential candidates of the value of a PhD degree in many phases of government and industrial activities, and not only in research and development;

   2) employers, both in government and industry of the premium value of the chemical engineer with a PhD in many phases of their activities in addition to research and development;

7. That, PhD programmes in addition to the usual scholarly goals, have as one of their aims an effort to develop entrepreneurship in students since this is a quality so badly needed at present in Canada;

8. That, since there is never a valid reason for producing a second- or third-rate PhD, no student be admitted into the graduate training programme, either at the master's or the PhD level, unless that student has obtained in undergraduate training, the equivalent of at least a B level;

9. That there be established a Post-Entrance Acceptance Committee (PEACE) composed of representatives from all the chemical engineering departments engaged in PhD education; and that this committee meet within a period of less than one month after the academic year has commenced, and that all acceptances be reviewed post facto, all available data being presented to this committee;

That, should it be found that students have been accepted who, in the opinion of this committee, do not fulfil the minimum requirements, the committee advise the Council of Ontario Universities that a recommendation be made to the requisite authority suggesting no Basic Income Units be awarded for that student;

10. That, either in the financing of PhD programmes or by other means, the Government of Ontario take steps to strongly encourage mobility among the graduates of the universities of the province so that a fair portion of them take higher degrees at universities other than at the one which awarded them their bachelor's degree;

11. That efforts be continued in the departments to group research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for the students;

12. That PhD programmes be the responsibility of only those staff members who have a proven or potential satisfactory research productivity and capability of supervising students; and

That consequently, universities adopt and publish policies which confirm the provision of equally valid career opportunities in other areas of university activities such as teaching, student guidance and administrative duties, for those professors who have no special inclinations to participate in PhD programmes;

13. That the case of a department which during the next five years has not maintained an average ambient population of at least ten PhD students of the caliber specified in recommendation 8, be reexamined by the appropriate authorities with a view to the temporary suppression of the PhD programme;

14. That the department at the University of Toronto, whose high standards are so well known, make every effort to see that these standards are disseminated throughout the Ontario system by recommending to many of its best undergraduates that they take their PhD training at another Ontario university; and

That efforts be made to attract stimulating students from other chemical engineering departments to take their place;

15. That the department at the University of Toronto pay particular attention to recommendation 11;

That in addition improvements be made to stimulate general students' interests by more seminars, regularly scheduled graduate courses, etc;

16. That the case of the department at Queen's University be given particular attention by ACAP in the light of recommendations 3, 12 and 13;

17. That the case of the department at the University of Windsor be given particular attention by ACAP in the light of recommendations 2 and 3, and in consideration of the present excessive number of departments of chemical engineering in Ontario; and

That this case be investigated in greater depth than the present study has allowed;

That, in the event of any action taken with regard to the present recommendation and recommendation 3, very special consideration be given to all aspects of the relocation of staff members who in the opinion of the consultants, are the responsibility of the Ontario university system.

4. CHEMICAL ENGINEERING AS A DISCIPLINE

4.1 Traditional Concepts

Chemical engineering began with a strong emphasis on applied chemistry. In its early years, chemical engineers developed unit operations as a basis for chemical engineering education and practice. The concept of the unit operations is unique with chemical engineering. It was recognized that chemical engineering processes and the process industries had definable operational steps which could be quantitatively described as unit operations. The unit operations served quite adequately as a base for chemical engineering education and the process industries for many years. Heat transfer, drying, filtration, mixing, evaporation, particle size reduction, absorption, distillation, and other unit operations were the foundation stones for chemical engineering as a discipline and the unit operations were synonymous with chemical engineering up to the end of World War II.

4.2 New Developments

During the two decades after World War II, chemical engineering began moving away from the unit operations as its fundamental educational platform to a more scientific rationale for education in chemical engineering. While it was still recognized that chemical manufacturing processes were composed of chemical reactions and unit operations, the sciences underlying these operations began to receive intense study through research in chemical engineering in both the universities and some industries. As a result, new insights and approaches were developed to problems involving the separation processes - the hallmark of chemical engineering. Thus chemical engineering research produced a rational approach to heat, mass, and momentum transfer and gave these processes the general title of the transport processes. Alternate titles have been transfer processes, and transport or transfer phenomena. Regardless of the title used, the scientific integration of these three basic chemical engineering processes laid a new foundation for chemical engineering education and research.

Another important post-war development which had major impact on all engineering research and education was the development of powerful, high speed computers. Computers dramatically changed chemical engineering design procedures; they opened entire new vistas for research in reactor design, process control, modelling and optimization of complex systems; they permitted exceedingly sophisticated new experimental methods in research whereby computers combined with new instruments can be used not only to control experiments but also to simultaneously analyze and process the results. Thus, modern chemical engineering research appears to be limited only by the ingenuity of the researcher and the availability of funds.

With the advent of the decade of the 70's, chemical engineering has had to expand its disciplinary horizons to meet the growing concern of the

impact of technology on society. Thus, chemical engineering plant design is now dramatically affected by environmental regulations and constraints; methods of environmental monitoring and control will require instrumentation development by chemical engineers: the growing need for energy will create opportunities for chemical engineering to develop new approaches to chemical energy sources and storage: e.g., a hydrogen energy storage economy. Society's continuing use of technological advances will in turn produce new challenges to all of engineering to eliminate potentially ill effects from technology's applications.

5. NATURE AND OBJECTIVES OF THE PHD PROGRAMMES

5.1 Student Qualifications and Requirements

It is unrealistic to discuss the PhD programme without at the same time considering the master's programme. The latter is very generally a prerequisite and although it has objectives and a market value of its own, it serves also as a screening process for admission to doctoral studies. Furthermore, some departments have combined requirements in course work for the two degrees.

The master's degree in chemical engineering is an excellent terminal degree for those students who do not seek a career in research and development. In actual fact, however, many of those who do obtain positions in industry find themselves involved in research projects.

There are two types of master's degrees available in Ontario engineering schools; one is the traditional scientific degree; the other is a master's of engineering directed toward professional practice. The ACAP consultants were cognizant of these degrees, and although the master's degrees were not the prime subject of evaluation, they were noted as being important but variable waypoints on the route to the PhD.

The obtaining of the master's degree is often a good occasion to move to another university for further training. This practice however, is not too frequent in Ontario.

Normally the screening process used by Ontario departments of chemical engineering starts with admission to the master's programme. This process is quite selective and great care is taken to accept only those students with proven scholastic achievements. Generally a 70% or B+ average at the undergraduate level is required plus recommendations from persons who know the candidate well. Large numbers of applications are received annually by practically all departments, mostly from foreign students, many of whose credentials are difficult to evaluate. The general impression is that the desired level of quality is maintained although some complaints were voiced that 'other' departments were accepting students of lower calibre. Many qualified admitted applicants do not register in the end simply because of the lack of financial support. This applies mainly to foreign students. Canadian students who if qualified, in general could preferentially obtain financial support, do not apply for a variety of reasons, e.g. availability of positions on graduation, an attendant fear of scarcity of jobs later, etc. It can be said that the total size of the student body in the master's programme in Ontario is limited at present by the availability of such financial support.

In principle the duration of studies is between one and two years. Although the lower limit is certainly appropriate, the higher one appears somewhat excessive. The fact that students seem to work shorter

hours than in the past may be a partial explanation of this. Another reason is that the chances of obtaining publishable results increase with the scope of the project and this is of great interest to faculty. Consequently, the total time required to obtain the PhD is increased accordingly with much more serious potential consequences.

Admission to doctoral studies is mostly based on staff judgements of the student's performance at the master's level. For students from other universities a staff committee usually examines the applications and recommendations. It must be noted however, that for admission to any level of graduate studies, the department has the authority to accept or reject an applicant but the final administrative decision to accept is the prerogative of the Faculty of Graduate Studies or its equivalent.

At the doctoral level, the student must usually take additional graduate courses and often undergraduate specialized courses in his field or in others. They are selected upon recommendation of the student's research director or advisory committee of staff members, again depending on the university.

The choice of a research supervisor is in principle a free one and follows interviews and discussions with faculty. However, many foreign students do not have the benefit of this free choice. Upon admission to the university they are many times told that only certain professors can offer them financial support and on the condition that they work in the field of the professor's choice.

PhD qualifying examinations are in the process of disappearing from those Ontario departments where they once existed. They are being replaced by sometimes totally different forms of examinations. There are many variations among the universities in this connection but everywhere this is taken very seriously. A typical form of this examination would be the written submission by the student of a so-called research proposal containing a survey of the literature, a description of the research project, of the apparatus and equipment to be built or used and of the experimental conditions together with the aims of the work.

In many departments the doctoral student has to give a yearly seminar on his research work.

The doctoral thesis is evaluated by a committee of three or four specialists in the field, one of them normally chosen outside the university where the thesis is presented. The oral presentation of the thesis is either private or semi-public. In the first case, only the committee is present: in the second, any interested person in the university can usually attend.

5.2 Training of Minds vs Training of Specialists

Doctoral studies in engineering on a sizeable scale are relatively new in Ontario universities, and for that matter in other Canadian universities, except for chemical engineering departments which have had a longer experience in this respect, possibly because of former associations with chemistry departments. They developed rapidly during the expansion years of the sixties. The programmes were modelled after those existing in the United States and also those in pure science in Canada. During that period everyone was too busy to spend anytime on the objectives of a doctoral programme. It was intuitively felt that the research work and the writing up of a thesis were the essential ingredients, together with a few advanced courses. The whole concept was more or less taken for granted.

During the aforementioned period, a large proportion of PhD graduates were absorbed by the university system throughout Canada. Since research money was available in increasing amounts and there were practically no other constraints, young staff members most naturally launched research projects which were, in practically all cases, a direct continuation of their own doctoral thesis. A notion gradually developed among themselves, their students and even the general public that they really were specialists in a given field or specialty. In a developing economy, this was taken for granted and of course influenced successive crops of PhDs.

For those new PhDs who took up employment in government departments or in industry, they very seldom had the same freedom except in the choice of job. However, they were less influential in shaping the directions of the on-going research programmes in universities.

When the economic recession of the late sixties came, the job market shrank appreciably. Universities were not hiring new staff at a rate comparable in any way with that of previous years and, also Canadian industries and government agencies curtailed very seriously their research activities, which had up to that time been an important job market.

Because many freshly graduated PhDs refused to accept positions in industry that did not involve essentially research activities and because many voices in the public began to be heard concerning overproduction of overly-specialized PhDs, the universities were compelled to re-evaluate their situation.

The concept of a PhD programme considered as a higher level for training engineers in solving problems of wider scope, began to emerge. It implies that a PhD is not necessarily trained for strictly research activities, and that he can and should envisage other possibilities, directly or indirectly related to research or development.

During discussions with faculty on the occasion of visits to the universities, it was found that this concept was quite generally accepted

although very few people had thought it necessary or useful to crystallize it in any form of a statement of objectives. While it is somewhat surprising that few chemical engineering departments made any detailed statement on this aspect in their written submission to ACAP, some of the expressions of the PhD programme philosophy and goals are noteworthy. In spite of their generality, the following excerpts bring out many essential points:

> "The object will be to train problem-solving engineers, whose knowledge is sufficiently broad that they can make themselves useful in a wide variety of endeavours. It is essential that the doctoral engineer have the depth and the breadth to innovate and invent. The depth in certain areas is necessary to provide the practical precision that is required in modern innovation. But a broad picture of the physical world together with a knowledge of markets and of industry is also necessary".
> (University of Toronto)

> "The object is to prepare students to adapt readily to any situation calling for a chemical engineering solution, and to utilize their problem-solving abilities, gained through research and courses during their PhD studies, in various areas of technology".
> (University of Ottawa)

> "To develop the full academic potential of students (...)
> To contribute to knowledge (...) to contribute to the maintenance of industrial strength and to foster the development of new strength in both primary and secondary industries".
> (Queen's University)

A detailed statement may not be absolutely essential and moreover complete uniformity among all universities is certainly not desirable.

It will suffice to indicate that the enhancement of the problem-solving abilities of the engineer is achieved through a combination, in proportions that can vary of the following elements:

a) acquisition of depth of knowledge through formal courses and personal study;

b) development of ingenuity and versatility in facing new problems or situations through various types of interactions with his research director, with other faculty and with fellow students;

c) training in intellectual discipline by means of seminar presentations and thesis writing.

The influence of the research director will of course be predominant and great care should be exercised in the decision to associate him with graduate students.

In some ways, the doctoral programme in chemical engineering will thus slightly differ from others, in pure science for example. Nevertheless it must be a scholarly endeavour which, while serving its primary purpose of training a future leader in his profession, contributes to knowledge and to the art of the engineer.

5.3 Nature of Research Project for Thesis

The type of training obtained by the PhD student depends on many factors: the general climate in the department, the size of the department and the resultant interaction with other students or groups, the particular conceptions of his research supervisor on engineering research and so on. But paramount among these will be the type of research in which he is involved during a period of three, four or more years. Although they are not easy to delineate, the following categories are frequently used: fundamental or basic engineering science, applied science and development, and finally engineering design. Chemical engineering research projects that can be identified with one or two of these categories have regularly, and still are, being carried out not only in Ontario universities, but all over the world.

5.3.1 Fundamental Engineering Science

During the last quarter of a century, a body of knowledge has emerged and has partly developed which is really a new realm which can be called fundamental engineering science. This is particularly true of chemical engineering.

Transport phenomena in their more basic aspects are a good example. The detailed knowledge of the behaviour of solids, liquids and gases when subjected to fields of various types of potentials, such as velocity, pressure, temperature and concentration potentials and of their behaviour in multi-phase systems, is really a part of science and is, in itself, quite remote from applied science or technology.

The complete understanding of multivariable chemical systems prior to their optimization by means of mathematical tools is another example.

In many cases scientists have abdicated or lost interest in traditional areas of their fields which are especially relevant to the needs of chemical engineers. This is true of thermodynamic properties of mixtures and of catalysis, for example. The chemical engineer has had to move into these fields in an effort to obtain the missing fundamental knowledge required for equipment design, for chemical reactor design, for fluid flow in porous media, fluid mechanics of complex fluids, etc.

This type of research is of course more curiosity-oriented than mission- or application-oriented. In many cases it is not distinguishable from the type of research carried out by many scientists. A graduate student involved in a research project of this type will evidently have to tackle

problems that are quite different from those encountered in strictly applied or mission-oriented work. His training will to a degree be closer to that of a scientist such that his viewpoint and approaches to problems will be in the manner of the latter, which differ in frame of mind and conceptions from those of the engineer.

5.3.2 Applied Science

The concept of applied science is much more difficult to formulate. Besides stating that it concerns the application of existing knowledge to a new or different situation, there is very little that can be added to clarify the definition without encroaching on the adjacent domains.

It may also be thought of as development although many will claim that it comes before development in the total innovation process. One convenient definition would be the transformation of science into technology. From the engineers' point of view however, this would involve development.

According to another interesting definition, applied science would be what leads to immediate practical or industrial applications: process, measuring or controlling device, material, service, etc.

This evidently not the archetype of university research in the traditional sense since the results of this kind of research work lend themselves less easily to publication in scholarly journals and since one of the missions of the university is the diffusion of knowledge.

Training in this type of research is useful to large numbers of chemical engineers; although it is encountered in doctoral programmes, it may receive less attention than it deserves.

5.3.3 Engineering Design

This has been the subject of much debate in the past. The engineer in effect, and even the one with the most complete training, will very frequently have to deal with design problems. In the wider definition of the term, design is the operation by which science or technology is complemented or supplemented by an input from the art, which may be experience exclusively, in arriving at a reasonable, and if possible the best, solution to a technical problem.

These considerations lead to apparent conflict with the traditional definition of scholarly work dealing with the pursuit of new knowledge exclusively. This conflict need not be more than apparent if the design work is genuinely original.

Very few of these theses are seen, but the importance of the training it would give the student warrants further experimentation in this avenue.

5.4 Trends in Ontario Departments

During the expansion years of the last decade, Canadian engineering schools have recruited their new faculty in a vast majority of cases among young PhD graduates fresh out of university or possibly having had a post-doctoral experience of one or two years in another university laboratory. Industrial experience is something of a rarity among engineering teachers hired recently.

This situation is the result of a sustained effort from practically all schools to increase the scientific content of curricula and to develop research and graduate studies. A very good measure of success has been achieved towards these goals, in particular by chemical engineering departments.

Research interests of younger faculty usually are in the field, sometimes quite specialized, in which they did their doctoral work. Furthermore, they are encouraged in this direction by the complete freedom given them by their main source of research funds, the National Research Council of Canada. It has been the policy of this agency, even with the recent austerity constraints imposed by the federal government, to encourage and generously support good original research. Its most important single programme, that of Operating Grants, has been in operation for many years in exactly the same fashion for university staff in engineering and in pure science. The Grant Selection Committees in the various branches of engineering evaluate applications by means of the same yardsticks as has always been current practice in the pure science committees: quality of previous work, scientific interest of proposal and productivity of the applicant. The latter, as measured by the number of papers recently published in refereed journals, is obviously the easier to use and has always been overwhelmingly important.

To adapt themselves to this system, engineering faculty have been increasingly drawn towards fundamental research which leads more easily to publications in scientific journals. As a result applied research and development have been seriously neglected.

Rather recently, the National Research Council has launched programmes of entirely different types which it hopes will divert part of the research interests of engineering faculty towards problems closer to the industrial reality. These new programmes have been received with great enthusiasm and if means of providing continuing support through them can be devised they will contribute immensely towards establishing a better balance between fundamental and other types of research. Such new programmes can also produce an increased demand for PhDs.

Another trend which is important in achieving this goal and which has become quite noticeable in Ontario departments of chemical engineering, is the funding of university research by mission-oriented federal and provincial government agencies. Here again the accent is on solving real practical problems.

These opposite trends show that professors are more versatile than we are sometimes given to understand and that universities need not be 'havens of irrelevant research'.

It should be remembered that doctoral work in chemical engineering is relatively new with one notable exception, in Ontario universities as well as in Canada at large. It is still time to shape the research programmes in a way that is suitable, as part of the normal activity of teachers of future practitioners.

5.5 Job Profiles for the Chemical Engineering PhD

The PhD chemical engineer has a remarkably wide range of job opportunities because of his broad education in contrast to other PhD disciplines. For reasons which are identifiable, the PhDs in chemical engineering appear to have a degree of flexibility which permits them to make substantial professional and technical contributions to many industrial areas, as well as in the managerial arena. This is due, in part, to the unique base upon which chemical engineering is built. It introduced very early into its educational programmes basic concepts which are finding popularity today under modern terminology. The early concepts of mass and energy balances (fundamentally related to stoichiometry), optimization of operations, mass and heat transfer analogies, etc., are now popularly taught as systems, optimization, modelling, etc. These have long been the chemical engineer's 'stock-in-trade'. As a result, he is especially flexible and adaptable to function in today's industry and society, because his educational concepts are applicable to a wide range of problems. A partial list of the fields open for PhDs in chemical engineering is shown below:

1. Process Industries (Chemical, Petrochemical, Minerals, Pulp and Paper, etc.)

    a. Development;
    b. Research;
    c. Management.

2. Government

    a. Environmental Control Agencies;
    b. Regulatory Bureaus;
    c. Consumer Protection;
    d. Research Agencies.

3. Private Research Institutes

4. Insurance Companies

    a. Reliability and Risk;
    b. Analyses and Forecasts.

5. Consulting

6. Education

7. Biomedical Engineering

6. ANALYSIS OF THE ONTARIO SITUATION

6.1 Combined Statistics, 1972-73

Table 6.1.1

Populations

	McMaster	Ottawa	Queen's	Toronto	Waterloo	Western	Windsor
Full-Time Staff	15	9	12	28	28	11	7
Full professors	7	4	4	16	13	5	2
Associate professors	3	2	5	6	10	3	4
Assistant professors	5	3	3	6	5	3	1
Bachelor's degrees awarded, 1973	14	7	39	51	67	8	9
Full-Time master's student excluding non-thesis degrees	27	14	9	38	19	34	4
Full-Time PhD students	14	14	11	29	36	15	5
Full-Time PhD students of Canadian origin	6	4	6	8	7	6	2
PhDs awarded, 1973	3	4	1	11	11	2	3
Post-doctoral fellows	4	3	2	12	13	0	0

Table 6.1.2

Research funds, excluding university-originated grants (1972-73)

	Total Research Grants	% of Faculty Receiving Grants	*Average Total Grant per Professor
McMaster	112,440	80	7,496
Ottawa	104,825	100	11,627
Queen's	72,200	83	6,016
Toronto	548,360	82	19,584
Waterloo	295,990	89	10,962
Western Ontario	123,500	91	11,227
Windsor	22,800	86	3,260

*These represent minima, since in some cases, 1972-73 data other than from NRC, were not listed, and some curricula vitae may have been incomplete.

6.2 Comments on Staff Size

Some important characteristics of the chemical engineering educational system in Ontario appear in Tables 6.1.1 and 6.1.2. One aspect of Table 6.1.1 that immediately comes to mind is the large number of departments offering programmes for the full spectrum of degrees: BSc or BEng., MSc or the equivalent and PhD. This is illustrated by the following comparisons based on estimated populations for 1971.

Table 6.2 [1-2]

Chemical Engineering Departments, Canada and USA

	Number of departments	Population (millions)	Dept/million
United States	138	207	0.67
New York State	13	18.6	0.70
Canada	17	21.6	0.79
Canada less Ontario	10	13.9	0.72
Ontario	7	7.7	1.10

[1] A.I.ChE., Chemical Engineering Faculties, 1972-73
[2] Grace, J.R., Chemistry in Canada 25 (7), 12-14 (1973)

The number of departments for Canada does not include Laurentian University, Royal Military College, UQAC and UQTR. Moreover, about 20% of U.S. departments do not offer PhD programmes. It thus appears that if the density of departments for the rest of Canada is of the same magnitude as in the United States, the Province of Ontario is much more richly endowed from this point of view. If Ontario had only six departments, the ratio would be 0.78; with five departments it would fall to 0.65.

The size of Ontario departments in full-time faculty ranges from 7 at Windsor to 28 at Toronto and Waterloo, the arithmetical average being 15.4. Two departments, Toronto and Waterloo, differ considerably from the others in size. In fact the average size of the other five departments is 10.6 which is very close to the 9.7 average for the rest of Canada.

There are many reasons for the large size of these departments. Both produce great numbers of bachelor's, each of them graduating approximately 80 chemical engineers yearly, a figure which is nearly double that of the closes competitor. In both departments, a non-negligible portion of the teaching load is devoted to undergraduate teaching of chemistry, physics or mathematics. Furthermore, Toronto, being a department of chemical engineering and applied chemistry, has a larger number of activities in the latter field. Finally, the cooperative system operated at Waterloo calls for a larger staff.

Thus, taking due account of special cases, Ontario departments appear to be close to the average size, the comparable U.S. figure being of the order of 9.

The total number of full-time faculty seems to have grown at a somewhat larger overall rate (19% compared to 14%) in Ontario than in Canada[2] as a whole for the four-year span ending in 1972-73. Noting that the figure for the entire country includes the rank of lecturer, there is some doubt that this difference is of much significance. However, the total number of full-time faculty has kept growing slowly during the last three years while it remained constant in Canada, again including lecturers.

The Ontario system makes up 55% of Canadian faculty in chemical engineering and trains 59% of the PhD students.

There does not seem to be in the departments any mechanism regulating their size, other than the operating budget provided by the Ontario Government.

6.3 Comments on Staff Qualifications

In an attempt to determine the desirable qualities of the thesis supervisor, one might arrive at a list such as the following:

- academic training to the PhD degree inclusive;

- intense research activity as evidenced by publication record, grants received, theses directed, invitations to lecture, etc;

- natural disposition to communicate easily with graduate students:

- availability (without exaggeration) to the students.

It is readily found that these qualities are more and more difficult to evaluate as we go down the above list. The last ones are next to impossible to assess but they nevertheless make the reputation of the advisor among actual or prospective students.

In all Ontario departments of chemical engineering the staff academic qualifications are all that could be desired with very few and very minor exceptions.

Of no department can it be said that the staff has a uniformally good record of publication or of theses directed, or of research grants received, with ages and experiences being taken into consideration. In many a case there is an excellent nucleus of faculty which carries the major part of the load and the rest of the personnel plays a lesser role. In other departments such nuclei are smaller and less visible. Each department has to be assessed separately.

6.4 Comments on Physical Facilities

All departments seem to be well-equipped with modern physical plants, including laboratories, offices, etc. The laboratories are well equipped. Facilities nowhere were found to be an obstacle to high-quality research.

6.5 Comments on Supporting Facilities

With relatively few exceptions these were found to be very good. Computer facilities are excellent everywhere. Shop facilities in general were satisfactory, although policies varied with respect to their use and accessibility. Engineering library holdings were found to be good. The inter-library loan system is a source of complaint in some of the universities. Other deficiencies are noted in the individual assessments.

6.6 Comments on Cooperation with Other Departments

In general cooperation with other engineering departments is good - in some cases this is deliberately fostered due to structure, but in most cases it is individual contact that is important. Cooperation with pure science departments, other than at the teaching level, was found to be in need of improvement.

6.7 Comments on Student Selection

The selection process actually starts at the admission to the master's programme since very few students go directly to doctoral studies after

their baccalaureate. Everywhere the applications are numerous but come mostly from foreign students. The departments then can and, in effect, all seem to maintain rigid admission standards. Above this there is the financial support difficulty which often prevents a student from accepting an admission offer.

The greatest danger would be the temptation to lower the standards of admission in favour of Canadian students since so few of them seem to show interest in graduate studies.

At the doctoral level, it can be said that each case is individually examined carefully. Student selection then seems to be very satisfactory.

6.8 Comments on Ethnic Origins of Students

One would normally expect that universities of a given province would draw most of their graduate students and especially their PhD students from that province or could attract others from Canada at large with an additional complement of foreign students. This is not at all the situation in Ontario departments of chemical engineering, but it is recognized that, it is not essentially different from the situation existing in practically all Canadian departments.

Ontario statistics indicate that the majority of PhD students over the past four years have been graduates from foreign universities, mostly in Asia and Europe. Moreover, between the years 1969-70 and 1972-73, the proportion of Canadians decreased from 43% to 31% of the total full-time PhD student body. During the same period the number of full-time PhD students remained practically constant with the exception of a 10% decrease in 1972-73. In absolute numbers, 60 Canadians were registered in 1969-70 but their strength had dwindled to 39 by 1972-73.

During the same period, the number of full-time PhD students having the landed immigrant status increased slightly to a figure of approximately 70. Foreigners with a student visa have been less important in numbers, averaging around 17.

It is interesting and important to realize the causes of such an overall situation, as it can be claimed that the present size of the chemical engineering doctoral programme is in excess of the apparent needs of Ontario students. It would probably be closer to reality to say that it corresponds more to the needs of faculty research activities and precisely to the financial resources made available by granting agencies.

In the early sixties, as the universities began to expand tremendously, doctoral programmes appeared everywhere both for prestige considerations and as a means of promoting healthy research activity among the staff. Budgets of granting agencies were also expanding at the time and the only real problem was to find the students to man the programmes. Jobs were very plentiful and interesting money-wise for graduating bachelor's in

all disciplines of engineering and it was difficult to entice them to stay at the university for graduate studies.

At that time, it was the general consensus among university faculty that the only possible method of building a graduate and especially a doctoral programme was to 'import' students. There began to appear in scientific magazines all over the world, advertisements offering stipends to qualified students. It was hoped that this would have an entrainment effect on Canadians. This never materialized fully, but developed in foreign countries a notion, still prevalent today, that financial assistance was easily available in Ontario and other Canadian chemical engineering departments.

Towards the end of the decade and early in the seventies, a number of reports originating from various sources, began first to hint, then to assert, that Canada was producing more PhDs, at least in some science and engineering disciplines, than it could use. Granting agencies, led by the National Research Council of Canada, began to restrict the use of their research monies to the support of Canadians or landed immigrants to the exclusion of others.

This new policy was not applied in concert with the Department of Manpower and Immigration with the result that the tendency for foreign students already in Canada to apply and easily obtain the landed immigrant status, was greatly enhanced. Those students who were in the system at the time were not affected by the new policy.

It appears that doctoral students in Ontario departments of chemical engineering having a landed immigrant status form a very complex group. A small number of them may be the sons of landed immigrants. Some probably came to Canada with the status, intending to settle permanently in Canada. It is almost certain however, that the vast majority of them were attracted by the bursaries offered by research directors from their research grants and by departmental stipends for part-time demonstrating. In all probability, they obtained the landed immigrant status prior to or after their arrival in Canada on the basis of appointments such as research assistants, lecturers, demonstrators, etc. The situation is further complicated by the fact that a number of them obtained their bachelor's degree at a Canadian university, possibly under special programmes such as the Colombo Plan.

One cannot help wondering what will happen to this group when the new immigration regulations begin to have their full effect, at a particular point in time when Canadians are not likely to replace them in large numbers because jobs are less plentiful for bachelor's who accordingly have a definite tendency to be much less 'choosy'.

Statistics may be too fragmentary and the period for which they are available may be too short to allow reliable conclusions on the effect

of limiting financial support to Canadians and landed immigrants. It has however, been claimed that a decrease in numbers due to these regulations could already be detected in 1970[3].

6.9 Mobility of Graduates from Canadian Universities

In a system of seven universities within one province, one would expect a fair amount of mobility among graduate students, in view of the obvious advantages for a chemical engineer to obtain successive degrees at different universities, thus broadening his views and his training. To these intrinsic values, there is the added consideration of equivalent costs to the students as scholarships are usually tenable at any university, and bursaries from grants are available almost everywhere for very good students.

There is no concerted action among the universities in this direction. On the contrary one can feel a strong tendency, very noticeable in smaller departments but by no means limited to them, to identify good prospective graduate students at the undergraduate level and to induce them to stay on at the same university for graduate work.

It is not surprising then to find a low degree of mobility among students and there is no reason to be satisfied with this situation.

Certain departments however, manage to attract to a fair degree students graduating from other Canadian universities. The data reported in Table 6.9.1 refer exclusively to students who obtained their bachelor's degree at a Canadian university and include graduate students at both the PhD and the master's level. They indicate for each department in absolute members and in percentages, the relative contribution of graduates from other Canadian universities to the total population of graduate students and to the population of students who are graduates from Canadian universities. They are based on the 1972-73 academic year[2] which saw a sharp decline (from 286 to 236) in the number of master's students.

The figures based on the population of graduate students with a bachelor's degree from a Canadian university are probably a better criterion as other factors such as the greater or lesser availability of research grants to support students or special arrangements with foreign countries may distort the picture based on the total population of graduate students. However, the two sets of figures show the same general trends.

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[3]Burns, C.M., Chemistry in Canada 24 (9), 16-18, (1972)

Table 6.9.1

Populations of graduate students with a bachelor's degree from another Canadian university in relation

	To Total population of graduate students		To Population of graduate students with a bachelor's degree from a Canadian University	
	Numbers	%	Numbers	%
McMaster	14/43	33	14/23	61
Ottawa	2/24	8	2/8	25
Queen's	4/22	18	4/16	25
Toronto	8/65	12	8/38	21
Waterloo	5/56	9	5/14	36
Western	11/30	37	11/16	69
Windsor	0/10	0	0/4	0
Ontario	44/250	18	44/119	37
Canada	80/476	17	80/221	36

These percentages, whatever the value of the criterion is, indicate the relative appeal of the graduate programmes (master's and PhD) at the Ontario universities to Canadian bachelor's in chemical engineering. These young people, in seeking a suitable university for their graduate training will in all probability be influenced by

- the reputation of a given university as it is perceived by themselves or by their advisors at their own university;
- recommendation from professors or friends, directing them to a particular research director;
- availability of unique research programmes in special areas or fields of interest: environment, biochemical engineering, etc.;
- availability of financial support;
- etc.

Most of these are partial criteria for excellence inasmuch as they would not persist for a very long time if they were not backed by excellence.

On the other hand, it is gathered from conversations with graduate students of foreign origin that before arriving in Canada, they did not know much about Canadian universities apart from what can be learned from calendars.

McMaster University and the University of Western Ontario seem to have a relatively high power of attraction for Canadians, the University of Waterloo being next. Although the University of Toronto has by far the largest number of graduate students who hold a bachelor's degree from a Canadian university it seems to draw them mostly from its own vast reservoir of bachelor's which is of the order of 75 yearly.

In spite of the fact that the year 1972-73 seems to be typical of the recent past, these statistics and conclusions are based on the student populations for that year only and should therefore be used with great care.

Considering the populations of full-time Canadian graduate students only, and with particular reference to the academic year 1972-73, the question may be raised as to which are the large departments and which are the small ones, as Table 6.9.2 will indicate.

Table 6.9.2

Populations of full-time Canadian PhD students

University	69-70	70-71	71-72	72-73
McMaster	13	14	9	6
Ottawa	5	6	6	4
Queen's	5	6	4	6
Toronto	22	17	13	8
Waterloo	10	8	9	7
Western	3	2	5	6
Windsor	2	2	2	2
Total	60	55	48	39

The smaller figures may be misleading as they may only represent the same students over the four-year interval.

6.10 Comments on Student Dedication

The results of the various selection processes before admission to doctoral studies can easily be seen. In all departments, the great

majority of the graduate students appear to be bright and articulate young people with a very clear conception of the type of training they are seeking and with strong determination to achieve a positive result.

The duration of doctoral studies has tended to increase in recent years. This may well be due to the greater complexity of the problems tackled and of the equipment and instrumentation needed rather than to students' lack of diligence. However, they do not seem to haunt the laboratories or libraries in the evenings like they used to!

6.11 Comments on Students Satisfaction with Programmes

The three consultants met in cameral with a representative group of PhD students in every department but one. In the latter case students were met individually in the presence of their advisor.

Almost universally, the students expressed satisfaction with the operation of the doctoral programme at their respective universities. The only exception met by the consultants seemed serious; it is dealt with under the appropriate heading elsewhere in this report. Topics such as the amount of guidance they were receiving, competence of faculty, the quantity and quality of support services available in library, computer and machine shop facilities, the adequacy of financial support, etc., were discussed frankly and openly. Students were encouraged to raise any issue they wanted.

6.12 Projected Student Populations and Degree Awards

Every department is deeply concerned with the consequences of the Ring of Iron report and of the ensuing action by CODE to gradually bring down the total registration of PhD students in engineering. They all realize that past growth rates cannot be maintained and they are prepared to consider much more carefully the size of their doctoral programme.

Table 6.12 summarizes the picture for the seven departments as it can be gathered from the documentation supplied and from discussions with chairmen and deputy-chairmen. In the case of the University of Toronto, the plan being "to prepare as many students as the market demands", the same number of doctoral students as in the past five years has been arbitrarily projected into the next five years.

If the populations were to increase according to the demands of the departments, this would probably correspond to an approximate increase of 10% in the total Ontario output of PhDs in chemical engineering. In view of the past employment record, this is not totally unreasonable.

6.13 Careers for Professors not Involved in PhD Programmes

Some faculty, for a variety of good reasons, feel little inclination for research work and are unsuccessful or only mildly successful at it.

Table 6.12

PhD Student Projected Population

Department	Staff Size 1972-73 (F.T.)	5-year period 1968-73		*Average desired PhD Student Populations for 1973-78
		Total PhD Output	Average PhD Student Populations	
McMaster	14	24	21	20
Ottawa	9	10	14	14
Queen's	12	7	10	12
Toronto	28	52	45	45
Waterloo	28	36	39	36
Western	10	3	14	21
Windsor	7	6	5	6
Total	108	138	148	154

*From the five-year plans submitted by the universities.

Others have become less inventive or productive with time. It is unfortunate that university tradition makes life difficult for them. The 'publish or perish' law still plays a great role in academic promotion and consideration. Some faculty then feel compelled to participate in research activity and while they contribute to the apparent size of the programme, they do not necessarily improve its overall quality.

Universities should develop plans to provide these staff members, who sometimes can be extremely useful in other functions such as teaching and administration, with conditions such that they can still have a respected career on campus. In a discipline where practitioners are being trained, one should also think of a new motto such as 'practice or perish'.

Such a situation is not a very serious problem in the Ontario system at the present time. At one or two universities however, it should receive appropriate attention.

6.14 Coverage of Fields and Specialties

The terms of reference of engineering consultants included a specific request to investigate and report on the "coverage of fields and specialties, and the extent of activity in each". As course work is only a small part of the total activities involved in doctoral studies and as there is nowhere a common core of mandatory courses, this is taken to refer to the research theme almost exclusively.

Since a compilation and classification of research activity of chemical engineering faculty in Canada is available yearly in published form through the Canadian Society for Chemical Engineering, a constituent society of the Chemical Institute of Canada, it was thought preferable to use it rather than dig out the information from the curriculum vitae of individual professors; the latter would also have presented a risk of non-uniformity of presentation and headings. The C.S.Ch.E. directory has been published for many years and has gained wide acceptance among the university community it serves. It must be noted that this publication is a directory of research and not of graduate studies: it therefore makes no distinction between research in master's or in PhD programmes or any other type of research. Nevertheless it is thought to give a reasonable account of the research areas available for doctoral work. Very few faculty active in research are not included in it.

The research areas are classified under eight headings, as follows:

A - Applied Chemistry
B - Chemical Reaction Engineering
C - Fluid Mechanics
D - Heat Transfer

E - Mass Transfer
F - Thermodynamics
G - Process design, Operation and Simulation
H - Miscellaneous categories

As a point of historical interest among other reasons for tabulation, it was thought desirable to extract Unit Operations from the Miscellaneous heading. They include in this particular instance: Mixing, Mechanical Separations, Drying, Crystallization and Solvent Extraction.

The summary for the year 1972-73 contained in Table 6.14 gives for each university and for the total system, the number of faculty actively involved in research work in the various areas. As most people are usually engaged in more than one research project, the total largely exceeds the number of faculty. It most also be remembered that it is sometimes difficult to classify a given project under only one heading.

The majority of activities classified under Applied Chemistry come under three sub-headings: Biochemical Processes, Air Pollution, and Water Treatment, the latter receiving more attention than the other two. Some of the work falling into the rest of the Applied Chemistry category does not seem to be different from conventional physical chemistry.

There were 108 full-time chemical engineering faculty in 1972-73 in the seven departments visited. Table 6.14 shows 220 'faculty-areas' in the nine areas. If all staff members were active in research, this would give an average of 2.1 areas of interest per faculty. On that basis, each number in the table would correspond to staff devoting half of their research time to a particular area. To obtain full-research-time equivalents the numbers should be halved but this would represent maximal numbers as not all faculty are active in research.

The main areas of chemical engineering are all covered in the total system and are well balanced. The less popular areas are Heat Transfer, Unit Operations, and Thermodynamics. In the case of the first two this corresponds to general trends in North America. Heat Transfer seems to have shifted at least partially into the realm of mechanical engineering and Unit Operations are no longer the challenges they used to be. Thermodynamics is not a field that is exclusive to chemical engineers and the low numbers in this area are no cause for alarm.

As for individual universities, it is quite striking that they all have some activity in practically all areas, except Western Ontario and Windsor. In the latter case, the obvious reason is the smaller staff size. For Western Ontario this is the result of a deliberate decision to concentrate in a limited number of areas. Other universities such as McMaster and Ottawa claim to have similar policies but it seems that the selected fields are so loosely delineated that there is no apparent

concentration, on the basis of the C.S.Ch.E. headings at least.

If a lower ration of areas/faculty really means more concentration on the part of the staff member on one main area, Toronto and Western Ontario and Windsor stand out in this respect. This ratio however, must be used with extreme caution as many factors influence it.

Serious consideration should be given, and probably is now given in some departments, to more effective grouping of interests with time. Obviously the process should not be carried out to its extreme limit.

Table 6.14

Distribution of research activities in Ontario departments

Area	Numbers of faculty active in each area (1972-73)							System
	McMaster	Ottawa	Queen's	Toronto	Waterloo	Western	Windsor	
Applied Chemistry	7	5	5	13	13	5	3	51
Chemical Reaction Engineering	4	4	4	7	10	3	1	33
Fluid Mechanics	6	2	3	5	5	4	1	26
Heat Transfer	1	-	1	2	3	-	2	9
Mass Transfer	6	5	4	5	7	-	-	27
Thermodynamics	1	1	3	2	2	-	1	10
Process Design, Operation, Simulation	5	2	3	3	6	2	1	22
Unit Operations	3	1	2	-	3	-	-	9
Miscellaneous	5	1	3	9	11	3	1	33
Total	38	21	28	46	60	17	10	220
Faculty (total)	15	9	12	27	28	10	7	108
Area/faculty	2.5	2.3	2.3	1.7	2.1	1.7	1.4	2.1
No. of fields	9	8	9	8	9	5	7	9

7. THE JOB MARKET

No special study on the job market for chemical engineering doctors was undertaken as the Thompson-Lapp[4] report became available, during the assessment period.

One school of thought firmly asserts that predicting and planning populations and degree awards in a given field is possible and necessary in view of the cost of training the students. It is claimed that statistical tools and methods presently available are of sufficient accuracy to permit the prediction of an operating band between optimistic and pessimistic boundaries. This is the philosophy of the Ring of Iron and the Thompson-Lapp reports.

Others believe that this is simply not possible because of the large number of unexpected and unpredictable causes and events that can affect short or long term trends. MacKay[5] has given a good semi-quantitative illustration of this point of view.

7.1 Chemical Engineering in Relation to Other Branches of Engineering

The ACAP chemical engineering consultants are primarily concerned with the career opportunities for the chemical engineering PhDs. The Thompson-Lapp report however, considers engineering as a whole and only occasionally does it refer to individual branches. Assuming, for the sake of discussion, that its predictions are correct and that its recommendations are accepted, two difficult questions would remain: 1) how would the doctoral student populations be allocated among the universities, and 2) how would the same populations be allocated between the conventional and emerging branches of engineering?

The first question is of course very political in nature and in any event outside the scope of a chemical engineering assessment. On the other hand, very serious consideration must be given to the second question. In this connection, it is very desirable to find some standard of reference and the obvious point of comparison is with the United States because of a close similarity between the two countries (and Ontario) in educational and professional patterns. There is also many common points between the political and economic systems of both countries, and especially if the focus is on Ontario as opposed to the rest of Canada.

A comparison can be made on the basis of doctoral output for chemical engineering in relation with all branches of engineering. Table 7.1.1 makes such a comparison. The data for Ontario and Canada are those of Thompson-Lapp and originated from the Canadian Association of Graduate Schools. It is to be noted that they differ by as much as ± 10% from those supplied for Ontario

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[4] Thompson, I.W. and Lapp, P.A., Supply and Demand for Engineering Doctorates in Canada, 203 p., Canadian Engineering Manpower Council, July 1973

[5] MacKay, D., Graduates in Science and Engineering: On Predicting the Demand and Controlling the Supply - Private communication - Paper submitted for publication to Science Forum

Table 7.1.1

Relative numbers of chemical engineering and engineering doctorates awarded in Canada and the U.S.A.

	Ontario			Canada			U.S.A.		
Year	Chem.Eng. Doctorates	Engineering Doctorates	Chem. Eng.%	Chem.Eng. Doctorates	Engineering Doctorates	Chem. Eng.%	Chem.Eng. Doctorates	Engineering Doctorates	Chem. Eng.%
1967-68	16	81	19.8	27	147	18.4	360	2933	12.3
1968-69	19	90	21.1	35	164	21.3	402	3387	11.9
1969-70	29	126	23.0	44	236	18.6	452	3620	12.5
1970-71	27	129	20.9	46	216	21.2	395	3640	10.9
4-yr period	91	426	21.4	152	763	19.9	1609	13580	11.8
1971-72							413	3774	10.9

by ACAP. They were used in preference to the latter solely to allow comparison with Canada. The U.S.A. data are from the U.S. Engineering Manpower Commission[6].

Although the data are not completely up-to-date, the four-year average is probably a better criterion to use than any trends, because of relatively tively small yearly numbers involved for Ontario. These results seem to indicate that a much higher proportion of chemical engineering PhDs are being trained in Canada and in particular in Ontario. Before drawing any conclusion, it must be remembered that in the U.S. a number of other specialties are available (which are non-existent or little developed in Canada) and have a tendency to divert sizeable numbers of students away from the more traditional disciplines. They include Industrial, Aerospace, Materials, and Nuclear Engineering plus Engineering Science and many others, accounting for approximately one-half of doctorates in engineering awarded in 1971-72 in the U.S.

It might be therefore informative to compare chemical engineering to the more traditional branches of engineering: civil, electrical and mechanical. This is shown in Table 7.1.2 for which the sources of data are the same as in Table 7.1.1. This new set of figures confirms the indications of Table 7.1.1 but shows a quite smaller difference between Ontario and United States. If the data involved are representative of 1973 and of the years to come immediately - and there is reasonable doubt in this connection - then the logical conclusion is that Ontario relatively is graduating more doctors in chemical engineering than is the U.S.A. This is substantiated by comparison of the number of degrees with populations. Thus, in 1971-72, the U.S. produced 413 doctorates for a population estimated at 207 millions in 1971; this gives a ratio of 2.0 doctorates per million; the corresponding figure for Ontario, based on an estimated population of 7.7 millions is 3.6. If it is assumed that Ontario produces or should produce 60% (see section 6.2) of the total number of doctorates awarded in Canada, the ratio becomes $3.6 \times \frac{1}{0.6} \times \frac{7.7}{21.6} = 2.1$ on the basis of a Canadian population of 21.6 millions.

The situation can then be interpreted as not too far from that expected, considering also that the proportion of doctorates in engineering to baccalaureates in engineering awarded six years previous has risen in Canada in recent years to a figure comparable to that of the U.S. (9.6 against 9.9 per hundred in 1970-71)[7].

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[6]Alden, J.D., Engineering Education 59 (3), 234-35 (1968), 60 (5), 399-409 (1970), 61 (5), 431-446 (1971), 62 (7), 799-808 (1972), 63 (7), 520-522 (1973)

[7]Thompson, I.W. and Lapp, P.A., Loc. cit. p. 93

Table 7.1.2

Relative numbers of doctorates awarded in chemical engineering and in four traditional branches of engineering

	Ontario			Canada			U.S.A.		
Year	Chem. Eng.	Four Branches	Chem. Eng.%	Chem. Eng.	Four Branches	Chem. Eng.%	Chem. Eng.	Four Branches	Chem. Eng.%
1967-68	16	61	26.2	27	110	24.6	360	1824	19.8
1968-69	19	70	27.2	35	141	24.8	402	2117	19.0
1969-70	29	98	29.6	44	191	23.0	452	2237	20.2
1970-71	27	89	30.3	46	186	24.8	395	2231	17.7
4-yr period	91	318	28.6	152	628	24.2	1609	8409	19.1
1971-72							413	2159	19.1

The privileged position of chemical engineering in Ontario is probably due to an earlier start and a better preparedness to take advantage of the expansion period of the sixties. It is to be expected that other provinces are or will be in the process of trying to recapture the lost ground on the assumption that higher education is a right of individuals and not a mission given to one or a few provinces.

A most important fact to remember is that the number of Canadians - exclusive of landed immigrants - registered in the Ontario chemical engineering doctoral system has always been less than half of the total, has dwindled by one third over the period 1969-70 and 1972-73, and shows no sign of immediate recovery. On the other hand, it is difficult to conceive how a student body of so-called landed immigrants can maintain itself in the future, in view of constraints imposed by research-granting agencies and by the Department of Manpower and Immigration. It therefore is not possible for the chemical engineering consultants to accept the conclusions of the Thompson-Lapp study, at least inasmuch as they would concern chemical engineering.

7.2 Optimistic and Conservative Views

It is the view of the consultants that forecasts on manpower needs have proven to be of very little use and should not be relied upon too much. They are much more worried about the lack of interest of young Canadians towards higher degrees which lead eventually to the more interesting and challenging jobs, for which on so many occasions in the past, doctorate holders had to be imported from abroad.

All departments claimed that they never had any difficulty in finding suitable positions for their graduating PhDs except in a very few cases of foreigners who had difficulties in adapting themselves to Canadian life. Moreover, it has repeatedly been heard in many of the departments that present demand is in excess of the supply.

In all likelihood, the market for PhDs in chemical engineering will soon develop at a greater rate again. First, there are many signs that the future is now much brighter for the chemical and process industries. In view of the increase in costs of natural products and of some of their shortcomings, synthetic materials play a far greater role in the economy. Biochemical applications will open up unthought of industrial applications in large numbers.

Furthermore, governmental initiative in selected fields such as the environment, energy and other resources, management, transportation, the North, the oceans, etc., will create through both government agencies and industry, a great need for highly qualified manpower.

Planning in the midst of an economic recession can lead to unduly pessimistic predictions and it is necessary to keep an eye on longer term objectives. PhDs in all disciplines and especially in engineering are tomorrow's leaders of society. They should be trained very carefully and in sufficient numbers.

Since we think of Canada as a free-enterprise society we must have faith in it, and accept the disadvantages that come with its great values. Doctoral studies are long in duration and their populations cannot adjust themselves quickly to changes in the economy. It is a logical consequence that there may be periods of oversupply and of overdemand of doctorates. The former should not be so serious since the PhD should be versatile enough to find a useful and challenging task to perform for society.

8. MCMASTER UNIVERSITY

8.1 Faculty

8.1.1 Quality

All members of the staff at McMaster are academically very well qualified and have a PhD degree. Remarkably none of them obtained it at McMaster and there is a great diversity in the universities where they were awarded: twelve universities or university departments are represented from Canada, Great Britain and the United States. This variety is certainly a positive factor, bringing different schools of thought, types of training and experiences to enrich the departmental melting-pot.

In effect, this department is really an energetic and dynamic team and each member is cooperating in an admirable fashion in the total educational effort.

Staff members are rather young, only two of them being over 43 years of age. Almost all of them have had some experience outside the university world, either in industry, government or in research establishments. The aggregate average for the whole department is over four years. A genuine interest in real problems exists at McMaster and there are a number of cases of research projects in cooperation with industry.

Ten of the staff members have records of PhD theses successfully completed under their direction and two more are presently engaged in their first experience at this level. Nearly all have past or present experience of supervising at the master's level.

8.1.2 Discipline Background

Four faculty members hold their first degrees in disciplines other than chemical engineering: two are civil engineers, one is a chemist and the other an applied chemist.

At the doctoral level, with the exception of two in chemistry, one in statistics and one in civil engineering, all were in chemical engineering.

8.1.3 Research Productivity

Twenty-four PhD degrees have been awarded in the department in the last five years and it seems that three or four staff members deserve the credit for the great majority of them. It should be noted that four faculty members have been at McMaster for less than five years. The younger professors seem to be in the process of picking up their share of the load.

The publication record of two of the professors is truly remarkable. For the others it is from good to very good with one or two exceptions, considering the age and experience of the personnel involved.

The data provided to the consultants indicate that the average NRC/DRB/MRC operating grants per faculty members receiving grants were lower than the Ontario and Canadian averages for the discipline in 1972-73. Again it must be remembered that the staff is rather young. Nearly all staff members are receiving such grants. A sizeable number of staff members received grants from other agencies and even industry in the last five years.

8.1.4 External Involvement

The McMaster staff seems to be performing its share of Faculty and University administrative and committee work.

Some professors are actively involved in cooperative research work for consulting with industry. One of them has formed a company. They are active in professional and scientific societies.

8.2 Research Programmes: Classification, Scope and Coordination

The department has a policy of grouping research efforts under five headings:

1) Process simulation;
2) Waste-Water Treatment;
3) Polymer Engineering;
4) Chemical Reaction Engineering and Catalysis;
5) Transport and Separation Processes.

A stronger emphasis is put on the first two categories.

These areas are sufficiently wide in scope to cover most of chemical engineering as can be seen in Table 6.14 where the emphasis placed on Process Simulation and Waste-Water Treatment can be easily identified.

University research coordination is not always easy to accomplish, but this Department has achieved reasonable success in this direction and seems intent on pursuing its goal.

8.3 Departmental Goals and Evaluation

The Chemical Engineering Department at McMaster expects to maintain a viable PhD programme with clearly stated objectives for continually strengthening and improving it. The department's general philosophy about the need for a PhD is pedagogically sound. The department is convinced that a vigorous graduate programme has the following values:

1) Intrinsically valuable for itself.

2) It contributes importantly to enrichment of the undergraduate programme.

3) It contributes significantly to the quality of the faculty.

The essential features of McMaster's goals for its PhD programme for the next five years as determined by the consultant team are summarized as follows:

1) Five research areas will be selectively developed with the recognition that a department cannot excel in every facet of chemical engineering.

2) The department does not intend to specify the numbers of students in each of the five categories of strength because students should have as free a choice as possible for their research topic.

3) The department has identified as an ideal goal 20 full-time equivalent PhDs per year. This goal allegedly would provide continuity of research programmes.

4) The department believes that its PhD graduates will not encounter employment problems because of the strength and quality of the research programmes of the department.

5) The department recognizes that there will be few faculty additions during the next few years. However, no plan was described for ensuring the maintenance of faculty vitality during this equilibrium period.

6) With respect to possible external constraints on the number of PhD students, the department "would play its part in working to such constraints, assuming that all universities cooperated in accepting the constraints and that COU adopted the recommendations of the consultants".

7) PhD candidates are encouraged to engage in research which cuts across disciplines and may involve direction from more than a single professor.

The department at McMaster appears to have established realistic goals and objectives which the consulting team believe to be achievable and productive. Possibly the most important omission in the goals was with respect to the question of how does the department plan to cope with maintaining faculty vitality during a period of equilibrium of faculty numbers. This does not mean such a plan does not exist.

8.4 Department Policies

The departmental policies at McMaster with respect to graduate admission procedures, scholastic admissions standards, and processing of application inquiries are professionally developed and operated.

8.4.1 Operations and Admissions

The department has established its own admissions standards which meet and exceed the minimum standards of the Graduate School. This appears to be normal practice for most departments of chemical engineering. The consultants found the department's operations with respect to admissions policies and operations quite satisfactory.

8.4.2 Examination Procedures

The Chemical Engineering Department at McMaster has developed a sound two-phase examination plan for its PhD candidates. These consist of a comprehensive oral examination on basic chemical engineering and a written plan of the candidate's research followed by an oral examination on the written plan. The only flaw detected in this plan was the fact that the research director has considerable input into the written plan. The consultants believe the PhD candidate should be required to have almost total independence in the preparation of the written plan.

8.5 Cooperation with Other Departments

Cooperation seems to be very good with other engineering departments at McMaster and with engineering departments in other universities in Ontario and elsewhere. There seems to be virtually no cooperative activities between the chemical engineering and science departments such as chemistry or physics. The criticism was voiced that these departments, although they sometimes paid lip service to applied science had too 'pure' an orientation. The basic science teaching to the undergraduate chemical engineers is however, done by the basic science departments.

8.6 PhD Students

8.6.1 Numbers

The number of PhD students at McMaster has averaged 21 during the four years preceding 1972-73, dropping to 14 during that year, after the awarding of seven degrees during the course of 1971-72. No difficulties seem to be encountered with a student body of that order of magnitude. The department itself wishes to maintain the 20-or-so level.

8.6.2 Origins - Inbreeding

This department has had a very good record of attracting graduates from other Canadian universities. Its reputation also keeps many of its own graduates at McMaster. At present at least, the ill-effects of inbreeding seem to be minimal because of the presence of graduates from other Canadian universities.

The department has also managed to keep the proportion of Canadians or landed immigrants having obtained their baccalaureate in Canada at or above the 50% mark over the period considered.

8.6.3 Length of Studies and General Level of Satisfaction

The average time to complete doctoral studies from registration in the graduate school to the granting of the degree seems to be 5-5.5 years.

The students are enthusiastic about their doctoral work at McMaster and they seem to be very satisfied with all aspects of their life: amount of guidance, competence and availability of faculty, cooperation between groups, support services, and even financial support. They seem to know exactly what their goals are and to be quite capable of reaching them.

8.7 Facilities and Services

The departmental facilities were found to be excellent, with relatively modern laboratories all well equipped with modern apparatus and instrumentation. Well-developed simulation techniques tend to make the graduate students 'engineering' conscious, rather than 'science' conscious.

8.8 Supporting Services

Computer facilities were found to be excellent and especially so in the area of mini-computers. The shops in the faculty were rated as excellent with good workshops available in the department. While the main library deserves the highest praise, the departmental reading room was in a state of disarray. While part of this was due to building reconstruction, discussion with graduate students led the consultants to believe that the room was usually not very useful.

8.9 Financial Support

The PhD students seem well supported financially averaging $4,500 per annum, which is obtained from a combination of contributions from research grants (~$1,800), teaching assistantships (~$1,800) and scholarships. Since the research grant input into the department is relatively large, there seems no financial hindrance to the maintenance of a fairly large graduate school.

In the graduate school (PhD and master's combined), averaged over the years 1968-1973, approximately 15% of students were supported by major scholarships (greater than $2,500).

8.10 Employment

All PhD graduates since 1969 were able to obtain positions or post-doctoral fellowships as shown in the following table.

Table 8.10

First position held
Summary for 1968-69 to 1972-73

Employer	Ont.	Rest of Canada	USA	Home Country	Other	Unknown
University	1	1				
Industry	5	1	2		1	
Government	4					
Community College or High School				1		
Fellowship		2			3	
Research (other than Fellowship)	3					
Other						
Unemployed						
Unknown						

8.11 Graduate School

The policies of the graduate school are comparable with those of most of the other universities visited. The graduate school has only nominal influence on the academic aspects of the PhD programme in chemical engineering, and contents itself with appointing committees for the PhD examinations, including the invitations to external examiners for thesis review and participation in the final oral examination. External reviews were claimed to maintain the research integrity of the department, and to satisfy the ethical concerns of the faculty members.

The philosophy was expressed by the Dean of Engineering that McMaster desires to develop strong graduate programmes as a high priority goal compared with the undergraduate programmes.

8.12 University Administration

The university administration at McMaster was not explored in depth. The general conclusion was reached that engineering, and chemical engineering in particular, were well supported by the university administration.

9. UNIVERSITY OF OTTAWA

9.1 Faculty

9.1.1 Quality

All members of the staff at this university are academically very well qualified and have a PhD degree. Remarkably, none of them obtained it at Ottawa and there is a great diversity in the universities where they were awarded: seven universities are represented from Canada, Great Britain and the United States. This variety is a positive factor again, bringing different schools of thought, types of training and experience to enrich the departmental intellectual climate.

The principal characteristic of this department is that it is strongly disciplined and united under a firm leadership and takes very seriously its task of maintaining and improving the quality of the doctoral programme.

The staff is rather young, six members being in the 42-49 age bracket and the three others in the 30-35 bracket. Almost all of them have had some experience outside the university world, either in industry or research establishments. The aggregate average for the whole department is over three years. The department seems to keep in close touch with the nearby laboratories of the National Research Council.

Only three of the staff members have records of PhD theses successfully completed under their direction but four additional ones are presently engaged in such supervision. All have past or present experience in supervising at the master's level.

9.1.2 Discipline Background

All faculty members hold their first degree in chemical engineering. At the doctoral level they were also all in this discipline except for one who specialized in applied chemistry.

9.1.3 Research Productivity

Ten PhD degrees have been awarded in the department in the last five years. It should be noted that three faculty members have been at the University of Ottawa for less than five years. The younger ones are all presently supervising either PhD or master's theses.

The publication record of two of the professors is truly remarkable. As for the others, considering age and experience, it is very good or good with only one exception. The department stands out as one of the best in Ontario in that respect.

The data provided to the consultants indicate that the average NRC/DRB/MRC operating grant per faculty member receiving grants were higher than

the Ontario or Canadian averages for the discipline in 1972-73, and all staff members at this department are receiving such grants. With very few exceptions, these are the only sources of research funds external to the university.

9.1.4 External Involvement

Staff members are active in professional and scientific societies to varying degrees. About half of them have acted as consultants to industrial firms.

9.2 Research Programmes: Classification, Scope and Coordination

This department has a policy of grouping research efforts under three major headings:

1) Thermodynamics and Transport Properties;
2) Kinetics, Catalysis and Reactor Engineering;
3) Transport Processes.

There has also recently been a shift of emphasis toward greater concern for the environment.

These areas are sufficiently wide in scope to cover a very large proportion of the total field of chemical engineering as could be seen in Table 6.14. This table shows the accent on the above-mentioned areas. The case of thermodynamics is a special one: even with only one active staff member, the activity is considerable.

There does not seem to be a definite policy for tighter grouping in the future.

9.3 Departmental Goals and Evaluation

The Department of Chemical Engineering at Ottawa follows much the same practice of other chemical engineering departments in Ontario by classifying its PhD research activities into areas or categories.

The department's stated goals indicated that in addition to continuing research in these areas, it intends to extend its "endeavours into fields such as Food Technology and Energy Engineering".

The department emphasizes that its research interests seek to "reflect the demands of our society, student interests, and the desire to serve the community". The implication of this emphasis is that the department intends "to take every opportunity to maintain viability, and to keep flexibility and versatility in doing meaningful graduate teaching and research, and to switch from one type or area of research to another whenever there is such a need".

The department is solidly convinced on the basis of past and present experience that its PhDs in the future will find meaningful employment

and career opportunities.

The department's present research programmes are in traditional and useful chemical engineering areas which have been of great value during the past decade. This observation, however, raises the question about the requirement for any university department engaged in PhD research, namely, that it should strive to be on the forefront or even in front of the present practice of its discipline. Although the department at Ottawa expressed intentions to move into new areas of technico-social importance, it has in fact not yet done so. It is realized by the consultants that problems and obstacles associated with moving into new physical facilities at Ottawa have been a major deterrent to maintaining existing programmes, let alone inaugurating new ones.

9.4 Departmental Policies

The policies of the department with respect to operations, admissions, and examination procedures for PhD candidates generally follow the same pattern as in other departments in Ontario.

9.4.1 Operations

Selection of new graduate students is coordinated by a professor charged with this function. He maintains liaison with other department professors and is kept informed of their desire for and ability to accommodate new graduate students. The amount of departmental funds available for new graduate student support is made known to him by the chairman.

9.4.2 Admissions

New graduate student acceptance is the prerogative of the departmental staff, as determined by majority vote. In the case of PhD candidate selection this prerogative is strictly observed and exercised. In the case of candidates for MASc and MEng degrees the chargé de sélection is given discretionary powers to accept new students.

A decision on acceptance is based on the usual combination of academic record and letter of reference. In general, a student must possess the equivalent of a University of Ottawa B average in his last two years of undergraduate studies to be accepted as a graduate student.

Formal admission or acceptance is done only after the School of Graduate Studies approves the department's selections.

9.4.3 Examination Procedures

The department's procedures on examinations for the PhD appear to be less clearly developed. Oral or written comprehensive examinations are given 'in certain cases'. Progress on research is presented in review to the departmental staff. The thesis is reviewed by two professors in the department, one other from within the university, and one from outside

and who is invited to attend the examination.

A general impression received by the consultants was that the department is still developing its procedures and policies for graduate students and that preoccupation with the design and construction of new facilities has placed a number of academic matters temporarily on a lower priority.

9.5 Cooperation with Other Departments

The department cooperates with other engineering departments, with the National Research Council, but feels its own chemistry department is too 'pure' in its outlook. The Chemical Engineering Department feels it is self-sufficient with regard to major pieces of equipment (along with those at NRC), so that the lack of interaction is not considered by them to be too serious. The teaching of the basic sciences to undergraduate chemical engineers is done by the science departments.

9.6 PhD Students

9.6.1 Numbers

The number of PhD students at the University of Ottawa has averaged 14 during the last five years. The department certainly can handle a student body of this size or even larger. It wishes to maintain this size and has in the past resisted the temptation to increase it, preferring to maintain better quality in students.

The department feels it has a special responsibility for the Ontario francophone community.

9.6.2 Origins - Inbreeding

The largest single group of doctoral students in this department during the last five years was that of foreign students who had obtained their first degree in Asia. However, the number of graduates from Canadian universities has gradually increased and is now very close to 50%. The department has been a little under the Ontario average in attracting graduates from other Canadian universities. A stronger mobility among students would certainly help it in preventing inbreeding. When Canadian students are scarce however, it is natural for any department to try retaining its own.

9.6.3 Length of Studies and General Level of Satisfaction

The average time to complete doctoral studies from registration in the graduate school to the granting of the degree seems to be 6-6.5 years. A partial reason for this must be the poor facilities available until recently.

Only a few students were interviewed. They were generally quite satisfied with all aspects of their life, with the doubtful exception of one

student concerning the advisor's availability. Those students that were interviewed seemed satisfied that this department was a good place for doctoral studies.

9.7 Facilities and Services

The department is housed in a new building with modern well-equiped laboratories containing capital equipment of the order of $500,000 which has been installed within the last few years.

9.8 Supporting Services

The computer, library and workshops were found to be excellent.

9.9 Financial Support

Graduate students are supported financially at a minimum of $3,800, a maximum of $2,400 coming from a teaching assistantship, the remainder from a research grant.

In the combined master's and PhD programmes, between 1968-69 and 1972-73, 28% of the students obtained major scholarships (greater than $2,500).

9.10 Employment

All PhD graduates since 1969 were able to obtain positions or post-doctoral fellowships as shown in the following table.

Table 9.10

First position held
Summary for 1968-69 to 1972-73

Employer	Ont.	Rest of Canada	USA	Home Country	Other	Unknown
University						
Industry	3					
Government						
Community College or High School	1					
Fellowship	5	1				
Research (other than Fellowship)						
Other						
Unemployed						
Unknown						

9.11 Graduate School

The School of Graduate Studies at Ottawa has more than minimal involvement in graduate programmes. Membership of professors in graduate studies is 'open to all' on recommendation of department chairmen. New graduate courses are reviewed by faculty councils for both the natural and social sciences. Significantly, the costs of new courses are now being critically examined. Theses examiners are appointed by the graduate school as is the case at all other universities visited.

9.12 University Administration

The understanding by the administration of the need and importance of graduate studies in a university was clearly enunciated by the Rector. The consultants received the strong and comforting feeling that the Rector, the Deans of Engineering and of Graduate Studies all have a deep awareness and conviction that unless graduate studies at the PhD level continue to be strong and viable, the university could be seriously damaged and its responsibility to enhance and improve society would be difficult to fulfil.

10. QUEEN'S UNIVERSITY

10.1 Faculty

10.1.1 Quality

All members of the staff at Queen's are academically well qualified and have a PhD degree, with one exception and in this case the work is now being completed. Remarkably, no one obtained it at Queen's and there is great diversity in the universities where they were awarded: ten universities are represented from Canada, Great Britain and the United States. This variety should be a positive factor again, bringing different schools of thought, types of training and experience to enrich the departmental intellectual climate.

It seems however, that the department has developed interest in a PhD programme rather recently and because of special efforts of the previous and present chairman. Possibly because of the previous lack of physical facilities, it does not appear to have gathered the same momentum as in other universities during the expansion years. The total climate has now improved however.

Only four of the staff members have records of PhD theses successfully completed under their direction and three additional ones are presently engaged in such supervision. All have past or present experience in supervising at the master's level.

A little over half of the staff has had experience outside the university and the aggregate average for the department is about three years.

10.1.2 Discipline Background

Eight faculty members hold this first degree in chemical engineering. The other disciplines represented are chemistry, applied chemistry, engineering physics and civil engineering. At the doctoral level, four disciplines other than chemical engineering are present: biochemistry, chemistry, sanitary engineering and statistics.

10.1.3 Research Productivity

Seven PhD degrees have been awarded in the department in the last five years. No new additions to the staff have been made for four years and the number of full-time doctoral students has remained rather small.

The publication records of two of the professors are very good; it is about average for approximately five others and low for the rest of the department.

The data provided to the consultants indicate that the average NRC/DRB/MRC operating grants per faculty member receiving grants were well below the Ontario and Canadian average for the discipline in 1972-73. Eighty-

three percent of the staff members received such grants in 1972-73. There is no other external source of research funds.

10.1.4 External Involvement

With one or two notable exceptions, faculty are only mildly active in professional or scientific societies. There is however, good participation in university affairs.

A deep interest and activity in Kingston's waste disposal problems should also be noted.

10.2 Research Programmes: Classification, Scope and Coordination

This department defines its research areas as follows:

1) Biochemical and Environment Engineering;
2) Chemical Kinetics and Reactor Design;
3) Process Control and Simulation;
4) Thermodynamics;
5) Transport Phenomena.

Here again the areas are so wide in scope that they cover most of chemical engineering. This brings a rather uniform distribution of the efforts under the nine headings of Table 6.14. There does not seem to be a definite policy for tighter grouping in the future.

10.3 Departmental Goals and Evaluation

The Chemical Engineering Department at Queen's has clearly given more than casual thought to its plans and goals for doctoral work over the next five years. Undoubtedly this is due in part to the fact that the university has been engaged in a study of its future during the next decade when the growth of the student body and faculty appears to be approaching equilibrium.

In general, the department plans "continued development of the course-work and seminar aspects of the programme, and pursuit of research in the five areas in which the staff of the department are currently active".

The department has attempted to make a realistic estimate of its capacity to supervise PhD candidates, and arrived at a capability ranging from 24 to 38 PhD candidates. However, based on consideration of factors such as enrolment patterns, climate for doctoral work in Ontario, changing interests of graduate students, employment prospects for PhDs and other factors which influence prospective doctoral students, the department estimates an annual enrolment during the next five years of from 10 to 15 PhD candidates.

The Chemical Engineering Department goals are based on experience, sound planning, and conservative programmes. The research areas of the department - on the books - would appear traditional, very similar in categories

to those of other departments, and without obvious 'new directions'. However, discussions with the professors suggest that strong interests exist to extend their special expertise into new areas of research. Thus, although the consultants sensed a certain aura of conservatism in both the department and the university, nevertheless the very excellent development planning and programme forecasting suggests that the department's goals and future research activities will be relevant and responsive to the prevailing needs of the province.

10.4 Departmental Policies

10.4.1 Operations

The Department of Chemical Engineering has done an excellent job in setting forth its procedures and policies on graduate studies for the information of the students. A 23-page departmental document outlines in detail most of the information which a PhD graduate student must know in order to progress toward the PhD degree. This document reflects considerable thought and planning by the department for which it should be commended.

10.4.2 Admissions

The admissions procedures and policies at Queen's are of standard quality and in general reflect a goal to maintain scholastic excellence in the graduate programme. No deficiencies were evident.

10.4.3 Examination Procedures

The department has developed an excellent set of procedures for evaluating the qualifications of a student who seeks the PhD degree. The required comprehensive examination is well conceived and eminently fair to the student.

The thesis examination follows the traditional practices of the province and involves an external thesis examiner.

In general the examination procedures at Queen's can be considered to be excellent.

10.5 Cooperation with Other Departments

Good cooperation exists between the Chemical Engineering Department, the various other engineering departments and science departments, e.g., mathematics, biology - but not with chemistry or physics. The teaching of the basic sciences to the undergraduate chemical engineers is done by the relevant science department.

10.6 PhD Students

10.6.1 Numbers

The number of PhD students at Queen's has averaged 10 over the past five years. The department could handle a few more students. It wishes to expand and it claims that its capability is double that of the expected student body of 10-15 for the next few years.

10.6.2 Origins - Inbreeding

Queen's is one of the rare Ontario departments that has maintained a majority of Canadian doctoral students in the department. This is due mainly to retention of its own bachelor's, a situation that is not too healthy and should be the cause of some concern.

10.6.3 Length of Studies and General Level of Satisfaction

The average time to complete doctoral studies from registration in the graduate school to the granting of the degree seems to be 5.5 years.

The group of PhD students met at Queen's gave a good impression of dedicated young people who knew what their aims were. They were generally quite satisfied with all aspects of their situation in the department: competence and availability of advisors, support services, etc. They think that Queen's is a good place for their doctoral studies.

10.7 Facilities and Services

The department is housed in a new building with excellent laboratories, office space and services.

10.8 Supporting Services

Ancillary services such as computing, library, machine shops were found to range from very good to excellent.

10.9 Financial Support

Of the master's and PhD students, 48% were supported by major scholarships (1968-1973) of value $2,500 or greater. The rest were paid from a combination of teaching assistantships and research grants. Stipends ranged from a minimum of $4,000 to a maximum of $5,500.

10.10 Employment

All PhD graduates since 1970 were able to obtain positions or post-doctoral fellowships as shown in the following table.

Table 10.10

First position held
Summary for 1969-70 to 1972-73

Employer	Ont.	Rest of Canada	USA	Home Country	Other	Unknown
University						
Industry	4			1		
Government	1					
Community College or High School						
Fellowship	1					
Research (other than Fellowship)						
Other						
Unemployed						
Unknown						

10.11 Graduate School

The graduate school's policies are similar to those of the graduate schools of other Ontario universities. Its principal functions, as far as departments are concerned, are to establish minimum academic standards for admission, review applications of prospective graduate students, and to appoint committees for PhD theses examinations.

10.12 University Administration

The recent acquisition of a Dean of Engineering of national stature who has a strong interest in the development of research at Queen's seems to augur well for the future.

11. UNIVERSITY OF TORONTO

11.1 Faculty

11.1.1 Quality

Members of the staff at Toronto are academically well qualified and have a PhD degree, save for four more senior members. About half of the faculty hold a degree from the University of Toronto, either at the bachelor's or the PhD level. For the higher degree, about fifteen universities in Canada, the U.S.A., Great Britain and Australia awarded them. There is enough of the necessary diversity to bring in different schools of thought and types of training to avoid inbreeding and produce a proper milieu. In addition, two-thirds of the staff members have had experience outside the university world, mostly in industry. The aggregate average for the whole department is five years.

This department has of course the longest history of a doctoral programme in Ontario and it is experienced and seasoned. Eighteen faculty members have records of PhD theses successfully completed under their direction and five additional ones are presently engaged in such supervision. Nearly all faculty have past or present experience in supervising at the master's level.

The age distribution in the department is probably the closest to Gaussian that can be found and this is, of course, helped by the size of the department.

The department seems to keep very good contacts with industry through institutionalized or individual consulting.

11.1.2 Discipline Background

It must be realized that this department is one of Chemical Engineering and Applied Chemistry. This renders the situation much more complex than elsewhere. Seventeen members of the staff hold a bachelor's degree in chemical engineering, six others were in chemistry and the rest is split among metallurgical engineering (2), engineering physics (2), civil engineering, mechanical engineering and physics. At the doctoral level, only thirteen degrees are in chemical engineering while nine are in chemistry; the remainder are in ceramics, physics, composite materials and polymers.

11.1.3 Research Productivity

Fifty-two PhD degrees have been awarded in the department during the last five years. This is by far the largest output of any chemical engineering department in Ontario.

At least half-a-dozen faculty members have an outstanding publication record and around fifteen others have a very good one. On the average, the department is certainly one of the best in Ontario. The number of patents held by staff members is quite impressive by Canadian standards.

The data provided to the consultants indicate that the average NRC/DRB/MRC operating grants per faculty member receiving grants were the highest in Ontario and probably in Canada for the discipline in 1972-73. Eighty percent of the staff received such grants in 1972-73. It must be noted that a large number of professors receive important grants from other government agencies or industry. Thus, money to support the total research effort in the department seems to be more plentiful than elsewhere.

11.1.4 External Involvement

In a department of this size, one expects to find a great diversity concerning involvement in university, civic, professional or scientific societies. Furthermore, the location of the department of Toronto makes it much easier to keep contact with industry through the large number of alumni.

Consulting by staff members seems to play an important role in their total activities but the department denies that it has any detrimental effect on purely academic endeavours.

11.2 Research Programme: Classification, Scope and Coordination

Without making a policy of grouping staff members in given areas of specialization, the department has, for its own use, eight categories to classify its research activities:

1) Applied Physical Chemistry;
2) Chemical Kinetics and Reactor Design;
3) Corrosion and Electrochemistry;
4) Nuclear Engineering;
5) Polymer Technology;
6) Thermodynamics;
7) Process Design and Simulation;
8) Heat and Mass Transfer.

Table 6.14 shows a rather uniform distribution in all areas with an emphasis on applied chemistry, which is quite normal for this department. Occasionally, two professors will team up for part of their research activities, but otherwise, the individual is completely free to select his own path.

11.3 Departmental Goals and Evaluation

The University of Toronto has expressed its goals as follows: "...it is our plan for the future to continue training as many students as we are able, to be competent, and hopefully even ingenious, problem-solvers".

The consultants reflected at length on Toronto's goals and objectives. The statement of goals was rhetorically entertaining, but not convincing.

On the basis of the consultants' discussions with the department chairman, it became apparent that the department's goals and philosophy were motivated and determined by a strong entrepreneur syndrome. This was underscored in the discussion about the Chemical Engineering Research Consultants Limited (CERCL) which has been established by department members. The philosophy of the department clearly stresses innovations, inventions, and the creation of private enterprises. The consultants' views on this departmental philosophy are mixed. One view is that, as a concomitant activity, it is not an especially stable base for graduate student education at the PhD level. Another view is that the faculty can become so preoccupied with the creation of companies and the solution of short-term problems, that the students are not given the appropriate or adequate instruction in research on a long-range basis. In the consultants' subsequent discussions with various university officials, the concerns expressed above were allayed. As a result, the consultants believe that wise departmental leadership can ensure a proper balance between the academic responsibilities of the faculty members and their entrepreneurial goals.

11.4 Departmental Policies

The policies of the Chemical Engineering Department at Toronto in many respects have unique characteristics. Probably the best description of the policies would be that they are 'real-world oriented'. The philosophy behind this orientation was the subject of considerable discussion, but the short time available for the consultants' visit may not have revealed the full depth and implications of the departmental philosophy.

11.4.1 Operations

The department's operations are best described as being fluid and versatile. In order to underscore the real world concept, the department members formed a corporation about ten years ago. This step was taken on the theory that the department should have real world involvement, and that older faculty should help younger faculty gain experience. The corporation, known as Chemical Engineering Research Consultants Limited (CERCL), has started 25 research programmes in small industries. There is much to be said for this philosophy, both pro and con. Again, it was difficult for the consultants to develop a clear assessment of the modus operandi of the department. Clearly, however, there appeared to be substantial enthusiasm for the real-world philosophy.

11.4.2 Admissions

Administration of graduate admissions policies is conducted by a staff member appointed as a graduate secretary. This person is responsible for approval of master's and PhD programmes and is concerned about graduate fellowships and support. Generally, the individual is in this position for three or four years. Admissions procedures are substantially the same as in other chemical engineering departments in the Province.

11.4.3 Examination Procedures

Examination procedures for the PhD candidate are generally similar to those of other departments in the Province, and there is a point during the candidate's career, usually after the first year, when the department decides whether he is eligible to proceed for the PhD. The thesis examination involves both faculty from Toronto and an outside thesis reviewer and examiner.

11.5 Cooperation with Other Departments

The department feels extremely self-sufficient since it is composed, in addition to chemical engineers, of some whose basic training has been in chemistry, physics, etc. Even though the research in the Department is extremely varied, very little evidence of inter-departmental cooperation is visible. Practically none comes from the chemistry and physics departments. Only one basic chemistry course taught by the chemistry department to undergraduate chemical engineers is required. For example, the teaching of chemistry courses is not done by members of the chemistry department, but by the Department of Chemical Engineering and Applied Chemistry.

11.6 PhD Students

11.6.1 Numbers

The number of PhD students at the University of Toronto has averaged forty-five over the last five years.

A population of forty PhD students represents 1½ students for every faculty member who has in the past been directing such students or who presently is. It is doubtful whether any increase above this number would be beneficial to these new students or to the student body as a whole, considering the present department attitudes toward the graduate students, and the support facilities available.

On the other hand, the department wishes to have as many students as it feels the market can absorb.

11.6.2 Origins - Inbreeding

The department has managed to keep among its PhD students a ratio of three graduates from Canadian universities to two graduates from foreign universities during the period of 1968 to 1972. However, in 1972-73, this ratio fell to unity. Since the department appears to have (or so appeared in 1972-73) the weakest relative power of attraction for graduates from Canadian universities (see Table 6.9.1) it must be concluded that the graduate student body contains a very high proportion of bachelor's from Toronto.

More mobility among Ontario graduate students would benefit departments and students alike. The present situation at Toronto is a potential source

of dangerous inbreeding.

11.6.3 Length of Studies and General Level of Satisfaction

The average time to complete doctoral studies from registration in the graduate school to the granting of the degree is of the order of 5.5 years.

This department is the only one where serious complaints were heard from PhD students. While they still think that their decision to take their PhD at Toronto was a good one, they are most unhappy about certain departmental attitudes and support services.

Some students claim, rightly or wrongly, that consulting takes so much of their advisor's time that they have difficulty in seeing him as much as they would need. Students criticize the department's apathy in organizing activities that would provide on a continuing basis a stimulating milieu for them, such as seminars. They claim that, of the numerous graduate courses offered on paper, too few are really given, too often selected for the needs of the practicing engineers who register in the course master's programme and thus given in the evening.

One universal source of discontent is the poor quality of the services obtained from the engineering library and to a somewhat lesser degree from the departmental machine shop and stores. Many students go regularly to a municipal library to read chemical engineering technical journals.

11.7 Facilities and Services

The chemical engineering building is now undergoing extensive modernization and shows promise of being converted to a first-class building. The type and quality of instrumentation are evidence of a mature, well-financed department.

11.8 Supporting Services

By contrast, some of the supporting services range from mediocre to very poor. The computer facilities are excellent. However, complaints regarding the engineering library were general among staff as well as graduate students. Complaints were vociferous, especially among the PhD students, about the lack of security systems which resulted in long absences of journals, books, etc. The students complained of a 4-6 month backlog in the badly-overloaded chemical engineering workshops. In the spring the situation was described as intolerable when 4th-year undergraduate projects saturate the shops. The store-room was also being renovated and enlarged but was found to be full of outmoded glassware and ancient bottles of chemicals. A major effort is needed in the area if this facility is to be useful.

11.9 Financial Support

Of the master's and PhD students (1968-1973), 45% were supported by major scholarships (greater than $2,500). The remainder received an average of $4,160, of which $3,360 came from the research grants and $800 for services as teaching assistants.

11.10 Employment

No unemployment problem exists for graduates of this department which produces the largest number of PhD chemical engineers in Ontario.

Employment statistics for PhD graduates of this department for the period 1969-73 are shown in the following table.

Table 11.10

First position held
Summary for 1968-69 to 1972-73

Employer	Ont.	Rest of Canada	USA	Home Country	Other	Unknown
University	9				1	
Industry	22	2	1	3		
Government	3			1		
Community College or High School						
Fellowship	3					
Research (other than Fellowship)	7					
Other						
Unemployed						
Unknown						

11.11 Graduate School

In general, the graduate school at Toronto has about the same role as the graduate schools of all other Ontario universities. Its influence is primarily academic, with very few funds available to support graduate activities of the departments. The consultants felt that in general the chemical engineering department was highly regarded by the graduate school and ranked high in comparison with other engineering departments.

11.12 University Administration

The university administration has just completed a study of the problems facing a university under a steady-state situation. There was clearly some concern and some uncertainty about the effect of CERCL on the hiring policy of the Chemical Engineering Department. There was also an apparent worry about whether young faculty were getting caught up into consulting activities too early in their careers. In a discussion on tenure policy, it was pointed out that new policies now being written will carry criteria for outside consulting. Without exploring the present tenure practice in depth, it appeared that tenure decisions were largely departmental in nature, starting with a recommendation from a departmental committee, with approvals going through the Dean, the graduate school, and certain cognate departments. The consultants were impressed with the realistic views of the Vice-President and Provost and his apparent insight into the chemical engineering department's activities.

12. UNIVERSITY OF WATERLOO

12.1 Faculty

12.1.1 Quality

All members of the Chemical Engineering Department at this university are academically well qualified and have a PhD degree. None of them obtained it at Waterloo and there is great diversity in the universities where they were awarded: nineteen universities are represented from Canada, the U.S.A., Great Britain, Germany and the Netherlands. This is certainly an extremely important factor in enriching the collective way of thought and methods of training students in the department.

Although the quality of researchers is by no means uniform, there is a large group of very productive people and there is an excellent spirit of cooperation among the staff, providing a stimulating milieu for students.

The age distribution of the staff is almost Gaussian, ranging from 29 to 53 years, which makes it a rather young group. Eighteen faculty members have had experience outside the university world, mostly in industry and the aggregate average for the whole department is four years.

Seventeen members of the staff have records of PhD theses successfully completed under their direction and four others are presently engaged in their first experience at this level. All but one have experience of supervising at the master's level.

12.1.2 Discipline Background

Six faculty members hold their first degree in disciplines other than chemical engineering: four in chemistry, and two in metallurgy. At the doctoral level, eighteen were in chemical engineering, six in chemistry, two in metallurgy and one each in controls and statistics.

It must be remembered that this department teaches more undergraduate chemistry than is usual for a chemical engineering department.

12.1.3 Research Productivity

Thirty-six PhD degrees have been awarded in the department during the last five years. This is the second largest output in Ontario.

At least four faculty members have a remarkable publication record and about a dozen others have a very good one. These form a high quality group.

The data provided to the consultants indicate that the average NRC/DRB/MRC operating grants per faculty member receiving grants were about average among Ontario departments but slightly above the Canadian

average for the discipline in 1972-73. Eighty-two percent of the staff received such grants in 1972-73, but there was no single very large (above $20,000) grant.

A large number of faculty members also receive sizeable grants from other agencies. Availability of research money is then not the limiting factor in PhD output.

12.1.4 External Involvement

Here again, a large department presents verying degrees of involvement in university, civic, professional and scientific societies. Waterloo is well located in an industrial area, allowing easier contacts with industry.

A moderate amount of consulting brings in some new ideas for research.

12.2 Research Programmes: Classification, Scope and Coordination

Historically, research activities in chemical engineering at Waterloo have fallen into five groups:

1) Biochemical and Food Engineering;
2) Extractive and Process Metallurgy;
3) Polymer Science and Engineering;
4) Mathematical Analysis and Control;
5) Transport Processes and Kinetics.

Here again, the scope is generally rather wide so that a large sector of chemical engineering is covered.

The groups exist to coordinate courses and to make more efficient the acquisition of research equipment, the use of space, the recruiting of students, etc. As new staff joined the department, it became natural for them to join one of the groups.

This classification corresponds generally to that found in Table 6.14.

12.3 Departmental Goals and Evaluation

The statement of goals and objectives for the Department of Chemical Engineering at Waterloo was less positive and definitive than the statements of other departments. The question of doctoral planning at the departmental level was avoided by the excuse that "...an atmosphere of rapidly changing provincial educational policies, ongoing re-negotiations of Federal-Provincial cost-sharing arrangements, and fluctuating student enrolment (our 1972 first year, undergraduate enrolment was 40% higher than in 1971 which, in turn, was 30% lower than 1970)..." makes planning "...slightly less meaningful than King Canute's effort at controlling the ocean".

As a result of the concern expressed above, the department's goal is set forth by the following statement of the department: "In such an atmo-

sphere of uncertainty and change, one can only adopt the objective of continuing to educate those high quality PhD students who are attracted to us. We can do this only by providing them with an environment in which high quality research is directed by strongly motivated faculty".

In spite of the rather diffuse statement of goals by the department, it was clear, as in the case of other chemical engineering departments, that Waterloo has endeavoured to group its research activities under five categories; a sixth group in Environmental Engineering is in an embryonic state and concerned at this moment only with course development. It is also worthy to note that the department intends to ensure research activities by the use of more post-doctoral fellows and hired research assistants (non-degree candidates) if this should become necessary.

12.4 Departmental Policies

Departmental operations are administered by a Chairman and two Associate Chairmen. There are 28 full-time faculty, with several generally on leave at any one time. All undergraduate students study on a Co-op Programme.

12.4.1 Operations

Departmental operations clearly are affected by the Co-op Programme, with a continual movement of groups of students into and from industry each term. At any one time, on and off campus, there are from 400 to 500 undergraduate students in the department. At the graduate level, five major groupings are identified which reflect existing research interests of the staff. However, not every faculty member can supervise PhD students.

12.4.2 Admissions

Admission practices again are somewhat the same as those of other departments, starting with the receipt of initial inquiry, followed by a chain of steps resulting in the final selection of qualified applicants. The department looks upon all incoming graduate students as master's candidates even if they already have this degree. This policy undoubtedly could result in a longer than necessary time spent in graduate study if an incoming student with a master's is indeed qualified to proceed immediately toward the PhD. In those cases where a graduate student has been in the system for thirteen terms, his situation is scrutinized by the graduate school to determine the cause.

12.4.3 Examination Procedures

The principal examination for a PhD candidate is the so-called 'propositional exam', for which the student prepares a comprehensive literature review and conducts some preliminary experimental work. All examinations are chaired by the Associate Chairman in charge of graduate studies. Thesis examinations again follow the usual pattern of a combination of departmental and university faculty plus an outside or external thesis examiner.

12.5 Cooperation with Other Departments

Cooperation seems to be very good with other engineering departments, but no cross-fertilization with physics and chemistry departments was noted (other than the occasional use of large pieces of equipment and one cross-appointment with chemistry). Chemistry courses are taught to the undergraduate engineers in part by the chemistry department.

12.6 PhD Students

12.6.1 Numbers

The number of PhD students at the University of Waterloo has averaged thirty-nine over the last five years. The department believes that these numbers will decline in the immediate future as fewer students become interested in PhD studies owing to fallacies spread by the media concerning the lack of demand for PhDs. Under these conditions, the department does not want to specify any desired number of students, but will strive to maintain or improve present quality.

12.6.2 Origins - Inbreeding

During the period 1968-73, the proportion of full-time Canadian PhD students to foreign students, has gone down gradually from 1 to 2 to 1 to 3 or less at Waterloo. This university has had the largest numbers of students from Asia and the Middle East. The department has had average success - by Canadian standards - in attracting students from other Canadian universities. At the same time, a small proportion only of its large graduating classes stays on for graduate studies. This may be the result of the operation of the undergraduate Cooperative Programme which builds into the student a tendency to take up permanent employment immediately upon graduation.

12.6.3 Length of Studies and General Level of Satisfaction

This university was the first to be visited by the consultants as a group and out of inexperience, they did not request a meeting alone with students. These were met individually, in presence of their supervisors so that the views expressed were probably less candid than elsewhere. At any rate, the students all seem to be well satisfied with their environment, and also with support facilities of all kinds.

The average time to complete doctoral studies from registration in the graduate school to the granting of the degree seems to be somewhat shorter than in most other departments at 4.5-5 years.

12.7 Facilities and Services

The department is housed in a new building with excellent facilities and laboratories. The equipment however, is all small scale, falling almost entirely into the 'engineering science' category, rather than in the 'engineering' one.

12.8 Supporting Services

Computing and workshop facilities were found to be excellent. While the departmental reading room and main library were classed as very good, yet complaints were voiced that great lacunae existed in the biological and biomedical science areas (needed for those in the area of bio-engineering). Complaints were also voiced about the inordinately long time it took for inter-library loans to arrive.

12.9 Financial Support

Graduate students receive a minimum of $4,500 per year. Of this amount, $3,300 is from a research grant (typically NRC) and $1,200 from the department for services rendered as teaching assistants.

12.10 Employment

Data re employment of PhD students (1969-1973) are shown in the following table.

Table 12.10

First position held
Summary for 1968-69 to 1972-73

Employer	Ont.	Rest of Canada	USA	Home Country	Other	Unknown
University	2	2		1	1	
Industry	7	1				
Government	2					
Community College or High School	1					
Fellowship		1			1	
Research (other than Fellowship)	4		2			
Other				5		
Unemployed	3					1
Unknown				1		2

12.11 Graduate School

At Waterloo, there is no graduate school or Faculty of Graduate Studies as such. However, there is an office with a Dean of Graduate Studies who chairs a graduate council. The main function of the latter was stated to

be the screening of PhD thesis committees and external examiners. Only informal ties exist between the graduate council and the departments of the university, which is more or less the normal state of affairs in most of the Ontario universities.

12.12 University Administration

No direct discussions were held with individuals at the top administrative level so that it is not appropriate for the consultants to comment on administration attitudes in the case of Waterloo.

13. UNIVERSITY OF WESTERN ONTARIO

13.1 Faculty

13.1.1 Quality

All members of the chemical engineering group are academically well qualified and have a PhD degree. One of them obtained it at Western Ontario and there is a good diversity in the other universities where they were awarded: eight universities are represented from Canada, the U.S.A., Great Britain and Australia. There is thus a good mixture of schools of thought and types of training bringing enrichment to the intellectual life of the group.

The latter is remarkable for its cohesiveness, its enthusiasm and its ability to take courageous policy decisions.

The age distribution is somewhat unusual. All are in the 43-49 age bracket except for two younger and one older staff members. It is a mature group, with varied experiences of doctoral programmes.

All members but one have had some experience outside the university world, either in industry or in government; the aggregate average for the group is over six years.

Five members of the staff have records of PhD theses successfully completed under their direction and the five others are presently engaged in their first experience at this level. All have experience of supervising at the master's level.

Great efforts have been made with good success to reinforce their group during the last decade.

13.1.2 Discipline Background

Two staff members hold their first degree in disciplines other than chemical engineering: one in chemistry and the other in bacteriology.

At the doctoral level, two were in chemistry, one in biochemistry, one in microbiology and the others in chemical engineering.

The name of the group in fact is Chemical and Biochemical Engineering.

13.1.3 Research Productivity

Only three PhD degrees have been awarded in the group during the last five years, as the doctoral programme is a rather recent endeavour.

Two faculty members have a remarkable research publication record and three others have a very good one. The rest is average or below average.

The data provided to the consultants indicate that the average NRC/DRB/MRC operating grant per faculty member receiving grants was slightly above Ontario and Canadian averages for 1972-73. Three-quarters of the staff only received such grants in 1972-73.

Some staff members also get research money from other agencies and from industry.

13.1.4 External Involvement

Many staff members are active in university affairs and a few are quite active in professional and scientific societies. Only a moderate amount of consulting is done.

13.2 Research Programmes: Classification, Scope and Coordination

As a consequence of a policy of the Faculty of Engineering Science, this group has deliberately selected four well-defined areas of research and all faculty members had to drop projects that did not fit them. These areas are:

1) Bio-engineering;
2) Fluid-Particle Systems and Fluidization;
3) Environmental studies;
4) Systems Engineering.

Table 6.14 shows, by the blanks left in the Western Ontario column, how selective this process was in comparison to the choice of other universities.

The increased emphasis on environmental studies is a consequence of the faculty's decision to follow the recommendations of the Ring of Iron report.

13.3 Departmental Goals and Evaluation

The goals of the Chemical Engineering Group at Western Ontario were set forth in considerable detail and in terms of each research area or category. Probably the major feature of the goals and objectives is the heavy emphasis on the development of environmental systems. The plan for the development of Environmental Engineering appears to have been soundly and thoroughly thought through and should be regarded as an important and desirable goal for the faculty and for the Province. In general, the research programmes and the respective goals appear to have a large measure of relevance in terms of the needs of industry, society, and the government. Furthermore, the goals of the group have strong and appropriate interdisciplinary characteristics and good ties with Canadian industry.

It would appear that the goals of the group have excellent prospects of producing PhDs with a strong fundamental understanding of basic chemical engineering coupled with a good perspective on the applications of this

basic knowledge to important problems of industry and the government. Furthermore, these interdisciplinary activities are very much in the direction, as necessary, for improving the interaction of technology with social problems. Under the leadership of the Dean of the Faculty, who is also a member of the group, the goal of developing a Centre for Systems Analysis Control and Design should make them especially strong in this much needed and essential area. The engineer in the next three decades must be well grounded in the concepts of systems, not only technical but sociotechnical.

13.4 Departmental Policies

13.4.1 Operations

Operations are similar to those of most of the chemical engineering departments of the Province, namely, the presence of a group structure based on classical engineering disciplines. This categorization or identification of research areas is probably convenient, but the group emphasized that it is not intended to be restrictive and encourages faculty members to enter into cooperative research with other groups and other faculties.

The group is effectively directed by a Chairman with administrative assistance from his staff. The procedures for handling the faculty needs are carried out effectively and with a minimum of red tape.

13.4.2 Admissions

The admissions practices of the group and the graduate school are fairly similar to those of the other departments visited, and adhere to standards which endeavour to ensure quality in the graduate students admitted. The University of Western Ontario, in common with the other universities, is faced with the problem of reviewing application requests for many foreign students and making decisions on maintaining a desirable balance between Canadian and foreign students.

13.4.3 Examination Procedures

PhD candidates are required to satisfy faculty standards through the usual system of examinations, which appear to be adequate tests of student accomplishment and quality. As in other cases, the thesis examination includes an external examiner selected by the graduate school.

The department encourages post-doctoral fellowship appointments, and currently has from six to eight in the department. Such appointments give strength to the research programmes.

13.5 Cooperation with Other Departments

The Faculty of Engineering Science is not set up on a departmental structure, so that it is difficult to assess the contacts of the chemical engineers

with the other engineering disciplines. Individual chemical engineers seemed to have good contact with other engineers in the Faculty. Virtually no contact at all occurs between the chemical engineers and chemists. The teaching of basic chemistry to undergraduate engineers, however, is done by the chemistry department.

13.6 PhD Students

13.6.1 Numbers

The number of PhD students at Western Ontario has averaged fourteen over the last five years. In contrast with many other departments, this number has been steadily growing from nine to twenty.

The group is not too keen on large increases for the immediate future; it would accept one additional student each year or every second year.

13.6.2 Origins - Inbreeding

The University of Western Ontario has been one of the most successful (with McMaster) in attracting a large proportion of graduates from other Canadian universities. This may have been due in a large measure to its specialization in bio-engineering and environmental studies. Foreign students have, however, been in large majority, as compared to Canadians.

13.6.3 Length of Studies and General Level of Satisfaction

The numbers involved are too small to allow a meaningful calculation of the duration of doctoral studies.

The PhD students are quite satisfied with all aspects of the working conditions in this group. The few sources of complaint that had existed 18 months ago during an assessment made by one of the consultants have apparently been eliminated.

13.7 Facilities and Services

The chemical engineers are housed in a relatively new building with very good facilities, although certain research areas, e.g., biochemical engineering, are housed in a so-called 'temporary' building. Every area seems extremely well equiped, not only with good laboratory equipment and instrumentation, but also on a macro level.

13.8 Supporting Services

The library, computer, and workshop facilities were all found to be extremely good.

13.9 Financial Support

Only 7% of students (1969-1973 average) were supported by major scholarships (value greater than $2,500 per annum). The others (from data

supplied by the department) received an average of $6,000 per annum (made up of $3,360 from research funds and $2,640 from teaching assistantships). This seems to contravene the COU dicta!

13.10 Employment

Since there were no PhD graduates in 1968-69 and 1969-70, employment data in the following table refer only to 1971-1973.

Table 13.10

First position held
Summary for 1970-71 to 1972-73

Employer	Ont.	Rest of Canada	USA	Home Country	Other	Unknown
University	1				1	
Industry		1				
Government						
Community College or High School						
Fellowship						
Research (other than Fellowship)						
Other						
Unemployed						
Unknown						

13.11 Graduate School

The Faculty of Graduate Studies is under the direction of a new Dean, who is very knowledgeable about the problems of graduate education and who appears to have capability and competence to cope with the shifting sands of new graduate programmes. The graduate school does involve itself in the development of establishing a select list of faculty members who can direct graduate work and supervise PhDs. In general, it appeared that the faculty has good relations with the departments and groups and is supportive of their needs to the extent of its limited financial capabilities.

13.12 University Administration

The administration of the university, judged from a brief visit with the Academic Vice-President, would indicate that Western Ontario has a progressive and forward-looking administration, which will ensure that the

academic programmes remain strong and that weak ones will be scrutinized with considerable care.

14. UNIVERSITY OF WINDSOR

14.1 Faculty

14.1.1 Quality

Five of the seven members of the Chemical Engineering Department are academically well qualified and have a PhD degree; a sixth one is in the process of obtaining it and the seventh compensates by a long industrial experience. The doctorates already obtained were granted by three universities, one in Canada and two in the U.S.A.

The Faculty of Applied Science has devised a scheme to compensate for the small size of its departments, by which research activities are carried out in faculty-wide units, built around themes so that the student may also interact with faculty members from other departments.

The department takes graduate studies very seriously and in the summer of 1972 made a hard decision to limit the number of students admitted to the master's programme.

The age distribution in the group is very wide, ranging from 30 to 58. Only three staff members have had experience outside the university but nevertheless the aggregate average for the department is about three years.

Four members of the staff have records of PhD theses successfully completed under their direction. All but the youngest one have a very good experience of supervision at the master's level.

14.1.2 Discipline Background

All department members hold their first degree and doctorates in chemical engineering.

14.1.3 Research Productivity

Six PhD degrees have been awarded in this department during the last five years.

Three faculty members have good publication records, but the remainder is fair or below average.

The data provided to the consultants indicate that the average NRC/DRB/MRC operating grants per faculty member receiving grants were well below Ontario and Canadian averages for 1972-73. Five staff members received such grants in 1972-73.

In addition, two professors share sizeable grants from other agencies.

14.1.4 External Involvement

Most faculty members have been or still are very active in scientific and professional societies. A fair amount of consulting with industry is reported; it is probably healthful for a department of this size.

14.2 Research Programmes: Classification, Scope and Coordination

In 1971, the Faculty of Applied Science decided that the research efforts should be reorganized to bring together around a research theme faculty members from various departments but with parallel research interests so that the teams could be stronger and thus provide the students with a more stimulating environment. One such theme is 'Engineering Process Design' and it so happens that chemical engineering research done at Windsor falls into that category under three headings:

1) Thermo-fluid research;
2) Environmental studies;
3) Chemical Process Design.

The transposition of this into traditional cagetories still results in dispersion however, as is shown in Table 6.14. This may simply indicate that too much importance should not be attached to classifying research projects into rigid categories.

14.3 Departmental Goals and Evaluation

The goals of the graduate programmes of the Chemical Engineering Department at Windsor will be effected by a proposed Divisional Plan for Graduate Studies. This plan would consolidate seven undergraduate departments under three graduate divisions of engineering process design, structures, and systems. There would be an elected chairman for each division. The proposed divisional arrangement is an effort to exert more control and planning for courses, and would determine the number and level of graduate students a division wished to enrol. This plan clearly indicates a realistic effort to coordinate the graduate programmes of its relatively small Faculty of Applied Science and to produce interaction of the several engineering disciplines. "Under this plan, the Chemical Engineering Departmental members find themselves entirely within the 'Engineering Process Design Division'."

The research plans of most of the individual department members, in general, indicate intentions to shift into new directions which are socially relevant and largely concerned with environmental problems. Over-all, these plans and goals appear logical and desirable. The stated intention of the department members to participate with various members of the process design division is an especially desirable objective.

The interest in so-called 'social engineering' appeared to be strong on the part of the department chairman.

The incoming new Dean of Engineering may alter some of the faculty's and department's stated objectives.

14.4 Departmental Policies

14.4.1 Operations

In a small department, such as at Windsor, policies and procedures do not require a high degree of formal structuring. With the small number of graduate students involved, clearly it is possible to treat each student individually, and minimize the need for highly structured operations and admissions procedures.

14.4.2 Admissions

Admissions procedures follow the usual pattern of processing letters of inquiry, review of application forms, etc. Quality standards are maintained in selecting graduate students.

14.4.3 Examination Procedures

Examination procedures were found to be somewhat similar to those used elsewhere, with some simplifications allowable because of the size of the department.

14.5 Cooperation with Other Departments

The divisional arrangement is an attempt to produce viable groups. Even though the total number of faculty members in a division (20) is still small, yet the arrangement should produce good interaction between disciplines, and is really the only way in which anything approaching critical size can be produced. Difficulties with the structure were voiced since obvious conflicts between the department and the division re authority, autonomy, etc., arise and await clearer definition. The teaching of basic chemistry with the exception of a few courses, to the undergraduate chemical engineers is done by the chemistry department.

14.6 PhD Students

14.6.1 Numbers

The number of PhD students has remained constant at five over the last five years. The department would wish to have one additional student immediately.

14.6.2 Origins - Inbreeding

Even though the small numbers involved do not justify the drawing of firm conclusions, it appears that Windsor presently has a low power of attraction for students from other Canadian universities. The department has no

other alternative than to draw its clientele from its own students and foreign students until it acquires more visibility on the Ontario or Canadian scenes.

14.7 Facilities and Services

Laboratories, offices and classrooms are adequate and meet the needs of the department.

14.8 Supporting Services

Supporting services such as workshops, library, computer facilities were found to be very good.

14.9 Financial Support

PhD students receive up to $4,620 per year, made up as payment for teaching assistantships and support from research grants.

14.10 Employment

All PhD graduates since 1969 were able to obtain positions or post-doctoral fellowships as shown in the following table.

Table 14.10

First position held
Summary for 1968-69 to 1972-73

Employer	Ont.	Rest of Canada	USA	Home Country	Other	Unknown
University						
Industry	2	1	1			
Government						
Community College or High School						
Fellowship	2					
Research (other than Fellowship)						
Other						
Unemployed						
Unknown						

14.11 Graduate School

The Faculty of Graduate Studies' relations with the various faculties are quite comparable to those of most other universities, namely, minimal. The leadership for graduate programmes and planning certainly is in the domain of the Faculty of Applied Science.

14.12 University Administration

There is obviously good rapport between the university administration and the engineering departments. Much positive leadership is offered by the top level of the administration.

15. CONCLUSIONS

The consultants for PhD programmes in chemical engineering spent approximately eleven days visiting the seven Ontario department of chemical engineering. On the basis of these visits, plus information provided in vast amounts on each department, the consultants were directed to evaluate their PhD programmes on a number of counts. The consultants, as academicians, believed that to make their assessment useful and valuable, they should be as critical of some of the forces underlying the reasons for the study, e.g. manpower forecasts, as they would be of the departmental programmes reviewed.

Following are the essential conclusions on which the recommendations are based:

1. Forecasts of manpower needs are generally unreliable. The consultants were skeptical of the value of such forecasts for long-range academic planning. It is virtually impossible to forecast with any reasonable degree of certainty employment trends in a field like chemical engineering. First of all, economists' forecasts, by their own admission, are so nebulous, that it is impossible to base firm predictions on these. For example, predictions in 1962 showed that, in virtually every scientific field, the PhD production in Canada would never equal the demand. Some six or seven years later, this was shown to be far from the case. Secondly, even if these forecasts were better than we think they are, in a specific area like chemical engineering, they could well be rendered invalid by a very simple government act such as, for example, putting a high priority on anti-pollution, etc. The consultants concluded that it is impossible to 'play the numbers' game' and propose quotas for each school, or indeed a quota for the provincial pool. It must be recognized that any quota established today deals with chemical engineers produced in 1977-79 and it would take a very brave person to predict needs for that time with any pretense of accuracy or precision.

   We do not subscribe to the formula laid down in the Ring of Iron which attempts to set an overall limit of 450 PhD students in engineering and then attempts on a formula based on undergraduate enrolment, to limit PhD students. This would obviously militate against schools that have specialized in graduate education and would, for example, put a school like California Institute of Technology in a highly inferior position vis-à-vis some of the larger State universities, if one would take an American example.

2. In evaluating PhD programmes, it is essential to recognize that as educational programmes they involve the lives and careers of students with high intellect, with above-average motivation and drive, and with potential to advance a nation's economic, cultural and material well-being far out of proportion to their numbers. Accordingly, PhD programmes cannot be evaluated on simple cost-benefit formulas, or

regarded as a commodity to be curtailed or expanded according to the fluctuations of the demands of the market place.

3. There is no question in the consultants' minds that if pressing technological-sociological problems are to be solved, technology will be essential to their solution. Chemical engineering will be a primary tool used in solving problems of the future, in the fields of environment, energy, resource management, recycling, etc.

4. Although the education of PhDs in chemical engineering in Ontario is designed primarily to serve the needs of the population of this province, yet traditionally a great deal of the needs of the rest of Canada (plus to some extent the U.S.A.) have been supplied by Ontario schools. Some Ontario undergraduates go elsewhere for their graduate training, hoping to return to their native province. In addition, a fairly large number of students will come to Ontario for PhD training from the rest of Canada, from other parts of the world, some expecting after graduation to return to their native habitat. Clearly, therefore, the Ontario chemical engineering departments fulfil a broad national need.

5. The consultants recognized that PhD programmes are among the highest cost programmes of higher education and accordingly the consultants are cognizant of the necessity to ensure that such programmes do not proliferate in an uncontrolled manner. Nevertheless, the consultants firmly believe that any chemical engineering educational operation must be vertically integrated so as to include the PhD, to some extent, bearing in mind the proportionably higher cost of such a programme. The case for this seems to be self-evident, even if one considers only the impact of the scholarly involvement of the staff member on the undergraduate teaching function.

   There is some evidence that the number of department of chemical engineering in Ontario is greater than called for by present needs. Therefore, it is logical to conclude that the Ontario government in friendly cooperation with the universities should consider procedures to consolidate the present system.

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APPENDIX B

DISCIPLINE GROUP RESPONSE

RESPONSE OF

CHEMICAL ENGINEERING DISCIPLINE GROUP

to the

REPORT OF THE ACAP CONSULTANTS

Preamble

The final report of the Chemical Engineering ACAP Consultants has been examined by the Discipline Group Committee consisting of representatives from the University of McMaster, the University of Ottawa, Queen's University, the University of Toronto, the University of Waterloo, the University of Western Ontario and the University of Windsor.

The Discipline Group strongly supports two basic positions taken by the Consultants. The first is related to the job market and the need for PhD programmes, as set out in section 2.5 of the Consultants' report. Engineering manpower predictions are indeed "precarious and hazardous endeavours", it is "difficult to assess the damage ...created by such erroneous forecasts", and it is clear that "a serious shortage of engineers can occur during the next five years". The Group also agrees with the view that, "the PhD chemical engineer by virtue of his education possesses such a powerful potential for career opportunities in a variety of fields that the question of the job market was not too relevant to the assessment".

The second basic position which the Group strongly supports is implicit in the Consultants' analysis, and is that the discipline of Chemical Engineering must be treated as a unified field, and must not be subdivided and reclassified into arbitrary sub-fields.

In general, the report and its recommendations were very well received by the Discipline Group. There are, as would be expected, some disagreements in emphasis and some in substance, and these will be discussed by direct reference to the individual recommendations.

Recommendation 1

We agree with the recommendation, with the understanding that inter-disciplinary actions are important and that some PhD graduates cannot be categorized into traditional groups exclusively.

Recommendation 2

Agreed.

Recommendations 3 and 4

We agree with recommendations 3 and 4, however, a combination of both could imply that a university temporarily not offering a doctoral programme should not offer a Master's or undergraduate programme - with this we do not agree.

Recommendation 5

We agree with recommendation 5 as it is interpreted by the authors in the light of section 2.5.

Recommendation 6

We agree with recommendation 6 and would welcome even stronger measures.

Recommendation 7

Agreed.

Recommendation 8

Agreed.

Recommendation 9

The Chemical Engineering Discipline Group has an informal agreement to review admissions annually on a province-wide basis. This is intended as a means of exchanging information, and as an opportunity to exercise moral suasion by review and discussion within the group. This we feel to be prudent and practical. Thus, we intend to implement the first two paragraphs of Recommendation 9 in a formal way but we reject paragraph 3 as an unacceptable mechanism.

Recommendation 10

The group agrees with this recommendation, with the understanding that such steps should not impair the right of the student to attend the school of his choice.

Recommendation 11

The group is concerned with the implications of a rigid interpretation of this recommendation. It does not follow that grouping of research into well-defined areas leads to the most stimulating environment for the students. If groups are too rigidly delineated, interaction among faculty and students in different groups may be stifled. Indeed, we believe that groups should be flexible and overlapping so that new ways of combining areas of expertise will arise easily.

Recommendation 12

We choose not to comment because this is a matter which is outside the area of special concern of the Discipline Group.

Recommendation 13

The group strongly believes that the size of a department is <u>not</u> an effective indication of the quality of its PhD programme.

The effect of this recommendation would be that an average enrolment of less than ten PhD students over the next five years would serve to initiate

a review of the quality of the programme at the university in question. The Group has no objection to the number ten being used to initiate a review of programme quality. However the Group is unanimous in stating that if as a result of this review a recommendation is to be made to suspend the PhD programme of the department concerned, then before this recommendation is made a review of the PhD programmes of all Chemical Engineering Departments in Ontario should be undertaken, and that any recommendation to suspend a PhD programme at an individual university should be made in the light of the complete assessment of the Ontario Departments of Chemical Engineering. This is regarded as a necessary protection for the quality of PhD studies in Ontario.

Recommendation 14

We agree as a discipline group with the desirability of student mobility within and outside of the Ontario system.

Recommendations 15, 16 and 17

These recommendations deal with individual universities and have not received the detailed consideration of the discipline group. We do however believe that there is not an excessive number of departments of chemical engineering in Ontario and we believe that the report does not present convincing evidence that there is an excessive number.

M. B. Bergougnou, University of Western Ontario
C. M. Crowe, Chairman, McMaster University
J. Downie, Chairman, Queen's University
B. C.-Y. Lu, Chairman, University of Ottawa
K. F. O'Driscoll, Chairman, University of Waterloo
R. A. Stager, University of Windsor
W. F. Graydon, Chairman, University of Toronto

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APPENDIX C

UNIVERSITY COMMENTS

Comments appear from Carleton, McMaster, Ottawa, Queen's, Toronto, Waterloo, Western Ontario and Windsor. (Carleton has no representative on the Discipline Group.)

CARLETON UNIVERSITY

RESPONSE TO FOUR ACAP ASSESSMENTS ON ENGINEERING

Introduction

Carleton takes the view that groups of disciplines should be evaluated before a clear picture of the situation within a single discipline can be obtained. Reports on any one component considered in isolation could lead to an erroneous judgement and unwise and precipitate action. Three consultants' final assessment reports have now been received for engineering disciplines in which Carleton is actively involved: Civil Engineering, Electrical Engineering, and Mechanical and Aeronautical Engineering. A fourth report deals with Metallurgical and Materials Engineering, of less direct concern to Carleton, while a fifth report, not yet received, will deal with Chemical Engineering, a discipline not represented at Carleton.

This response will address itself to the four reports which have been received and examined to date. We may wish to add further comments when the fifth report has been studied.

We sense a good deal of unanimity on a number of fundamental questions among the fifteen consultants involved in the four reports so far received, a communality of viewpoint which we share and endorse. We believe that Engineering has been most fortunate in having the assessments carried out by a group of consultants whose international stature, valued judgement and perspective give authority and credibility to their studies and reports. In general then we accept their findings and subscribe to their recommendations with only a few exceptions to be noted later.

In this response we shall deal first with those matters which we believe to be basic and general in nature and leave until the end our views on specific points raised in individual reports.

Matters of a Fundamental or General Nature

1) Control of Student Numbers:

The four reports are unanimous in their opinion that previous estimates of the demand for engineers with doctoral degrees, notably those in the Lapp Report of 1970 and the report for CEMC of 1973, have erred seriously on the low side. They point out that there is no evidence of difficulty in obtaining jobs by students close to graduation, nor do they foresee difficulties in the future except for those which normally occur in highly specialized areas.

The consultants reject the notion of quotas applied to departments to control student numbers, in part because the demand seems likely to exceed the supply than the reverse, making quotas unnecessary, but in the main because they feel that other means of control are to be preferred. The report on Electrical Engineering puts it this way: "The number of doctorates granted in electrical engineering (should) be determined by:

(i) availability of qualified students

(ii) maintenance of adequate standards by the universities, and

(iii) the existing capacity (staff and facilities) of the universities for giving adequate training." The Mechanical consultants refer to emerging natural controls and go on to say: "We would wish the resources of the present system, which are predicated principally on undergraduate requirements, the market demands, the quality of the programme and the good judgement of the departments to determine the total number within the system."

Carleton subscribes fully to these views. We believe that rather than through centrally imposed quotas or limitations the universities individually should control numbers by restricting admission to students showing high promise and by maintaining adquate standards. The latter together with the market demand will provide an adequate control. We would be prepared to support the development and adoption of an evaluation scheme, such as the scholastic index used at Carleton, which can be applied across all disciplines and which could be used in the monitoring of admission standards which we believe should be a matter between a university and OCGS. We believe,

however, that the interpretation of these standards for individual student cases should be left to the informed judgement of the university concerned.

2) Quality of Existing Programmes, Suggestions for Change:

From their comments on the quality of the Ph.D. programmes for the system generally, it is clear that the consultants believe it to be quite acceptable. The Civil consultants point out that "the system provides a good quality coverage of the field and specialties without undue overlap on a regional basis." Comments on individual universities draw attention to departures from the norm in both directions.

A common theme running through the reports is the need for greater flexibility in the future. The Metallurgical and Materials consultants state it this way: "As Canadian industry becomes more sophisticated and has to rely on more advanced technologies, it will have to learn how to fully utilize the talents and skills of Ph.D. graduates and the universities will have to learn how to develop Ph.D. programmes which produce imaginative engineers capable of responding to these new opportunities." These consultants also recommend that programmes be so designed as to permit graduates from other specialties to change specialties as they commence Ph.D. work.

The consultants also show a degree of consistency regarding the need to shift the emphasis in Ph.D. programmes to meet the situation of the seventies. The Electrical consultants state it this way: "The education of Ph.D. students in areas of national need is a more efficient use of resources than is a random choice of fields followed by a period of retraining." In relating it to their field, the Civil consultants state that there should be "less stress on traditional areas, particularly structural engineering, and more stress on multidisciplinary education, environmental engineering, and transportation." The Mechanical consultants recommend a greater emphasis on production engineering and design.

Close contact between universities and industry is felt to be important by all the consultants and individual universities have been singled out for commendation where this contact is regarded as exemplary while others have been asked to improve in this respect.

Once again Carleton accepts the findings of the consultants on the quality of the existing programmes and their views on the nature of Ph.D. programmes required for the immediate future. We feel that we have already

made considerable progress toward achieving the desirable objectives set out by the consultants and that we have received adequate recognition for this in their reports.

3) Critical Size:

The Engineering consultants are far less concerned about the concept of critical size than the consultants who carried out some of the earlier planning assessments, and show as much concern for the disadvantages of "bigness" as of "smallness." The Engineering consultants place their primary emphasis on the quality of the student and of the faculty rather than on size, a view which we heartily endorse.

The Mechanical consultants take the strongest stand against the notion of critical size. While admitting the advantages enjoyed by a large group, they go on to express their view that "a drawback to the large group is the difficulty of adapting to change" and further that "the groups in the smaller departments often displayed an original point of view and a willingness to adapt to change that was not apparent in the larger and longer established departments." They found more cross linkages between departments and a greater tendency to establish outside contacts with government and industry in the smaller faculties. They conclude: "In our view no creative group, and no capable individual within such a group should be denied support because it is small." The Civil consultants echo these views: "Size is not a sufficient criterion for judging whether a school can offer a Ph.D. programme" and also "there is no a priori reason why a small school cannot provide as satisfactory an environment for the student as a large school."

The Electrical and Metallurgical and Materials consultants are not as definite on the matter of critical size as the Civil and Mechanical consultants. The Electrical consultants felt that a desirable size for a department fell in the range from 10 to 20 faculty with from 10 to 20 students enrolled but expressed the view that "high standards of excellence with emphasis on quality rather than quantity will pay off in the long run." The Metallurgical and Materials consultants draw attention to the contrast between the British approach to Ph.D. education centered around the thesis and requiring only one good faculty member and the American view that a

courses because of the importance given to course work in the American approach. The consultants themselves took the position that students should be taught by members o. the basic science departments as well as by Engineering faculty members and that the critical size of the core depends a great deal on the strengths in related disciplines. The latter factor seems to have been ignored by some of the consultants who assessed the non-Engineering disciplines.

As indicated above, Carleton is fully in agreement with the position on critical size taken by the Engineering consultants and does not support the views of the Chemistry or Economics consultants nor ACAP's views on this matter.

4) Proportion of Foreign Students:

All four of the reports under review make reference to the enrolment of foreign students in the graduate programmes at Ontario Universities.

The Electrical consultants noted that the percentage of doctoral students with first degrees from Canadian universities was consistently in the range from 47 to 51 over the past five years. They believe an ideal mix should involve students with a variety of backgrounds coming from various universities and should include some students from foreign countries. The latter they feel should be in the minority and they suggest 25% as an appropriate proportion. The Civil consultants expressed concern also at the low percentage of full-time Ph.D. students who had obtained their first degree in Canada but remarked also that the percentage was much higher for part-time students and suggested that part-time studies should be encouraged.

The Mechanical consultants, while noting a similar proportion of non-Canadian first degree students to those mentioned above concluded that we cannot count on Canadian undergraduate schools to provide candidates in sufficient numbers and that we must continue to rely on students from abroad. The latter would likely decrease in number in the future due to recent policy changes with respect to immigration and financial support for students without landed immigrant status. They suggest that support for such students should come from appropriate federal agencies such as CIDA.

The Metallurgical and Materials consultants find that "Canadian industry unable to fill its vacancies with Canadian graduates of Canadian

origin has preferred to import graduates from British or Australian origin rather than employ Canadians of Asian origin." They recommend an intensification of efforts to recruit a larger proportion of Ph.D. students from the graduates of Canadian universities.

Carleton is in agreement with the consultants concerning the desirability of having a mix of students from different universities in Canada and from foreign countries and in having a reasonable balance between Canadian and non-Canadian first degree holders. The problem of foreign students is usually expressed as one of controlling their number. We believe that the recent immigration and financial restrictions imposed on this group is likely to overshoot the mark and the problem in the future may well be one of too few rather than too many foreign students. A more serious problem is that of too few graduates of Canadian schools embarking on Ph.D. work.

Comments on Some Specific Matters

In this section we wish to deal with some specific issues raised in individual assessment reports.

1) Civil Engineering Doctoral Planning Assessment:

The references to Carleton University throughout this report are generally favourable and on the whole we like their conclusions and recommendations. There are, however, one or two points we wish to question.

In Recommendation 3 the consultants suggest "there is a case for more consistent requirement of acceptance for Ph.D. students between universities." We are uncertain as to the meaning of this since it is not discussed in the body of the report. We have expressed the view earlier that there should be a system, such as Carleton's scholastic index, for evaluating students across all disciplines, and that OCGS might monitor standards of admission generally. We do not see the need for an external person on acceptance committees but continue to support the position that there should be external examiners on thesis committees.

We cannot accept the proposal in Recommendation 5 concerning the collapsing of the Ph.D. B.I.U.'s into the undergraduate B.I.U.'s although we can support the objective. We believe that a major re-examination of the

formula for providing operating funds to the universities is called for, not just minor adjustments to B.I.U. weightings.

We do not see the necessity for the further proliferation of degree designations which would result from the introduction of the Doctor of Engineering Degree included in Recommendation 12. We support fully the consultants' concept of a range of possibilities for a doctoral thesis, from the mathematical or theoretical at one end to the design or application-orientated at the other end, but we believe the requirements for the Ph.D. should be flexible enough to permit this as is the case at Carleton.

2) Report on Doctoral Programmes in Electrical Engineering in Ontario Universities.

For the purposes of assessment and reporting, the consultants have combined Carleton's departments of Electronics and Materials Engineering and Systems Engineering under the discipline title of 'Electrical Engineering.' Their comments, conclusions and recommendations apply uniformly to our two departments. We regard this report as a highly competent and thorough piece of work. The analysis in the earlier sections prior to the evaluation of departments gives to the whole a degree of credibility that is probably unique in such reports.

Carleton University has received a uniformly favourable assessment in Electrical Engineering. The Ph.D. programmes in both departments are considered to be "strong." The interaction of Carleton with laboratories and firms in the Ottawa area is described as a "model" while our programmes are praised as having "unusually high contemporary relevance."

We intend to pursue our proposed five-year plan for the graduate programme in Electrical Engineering; we believe that our present organization into the two departments of Electronics and Materials Engineering and Systems Engineering is the most appropriate and effective for our purposes and intend to maintain this organization.

We have noted the general recommendation that only students showing high promise for graduate work should be accepted into the Ph.D. programme. We endorse this recommendation.

We plan to aim for the small growth in graduate student numbers proposed in the five-year plan, but note that in the consultants' view this growth is modest. We shall allow ourselves to be responsive to the applications which we receive from well-qualified students. We expect that our growth will be limited to a natural and non-excessive rate by the limited availability of good applicants.

We believe that it is possible to increase the scale and effectiveness of our associations with laboratories and firms in the Ottawa area and shall endeavour to exploit further such interactions.

The recommendation that greater use be made of graduate courses given at the University of Ottawa is accepted. The establishment of a close working relationship over the last two-year period has made the sharing of course offerings and facilities a natural outcome which it is intended to exploit.

We accept the report of the ACAP consultants without reservation. We consider the assessment to have been fairly and thoroughly done and believe that the report as a whole will be of considerable benefit to the Electrical Engineering profession in Ontario and Canada.

3) Report of the Mechanical Engineering Consultants:

We accept the ACAP consultants' report on Mechanical (and Aeronautical) Engineering without reservation. We consider it to be a valuable, authoritative, well reasoned document. The report is thoroughly credible because of the competence and international stature of the consultant team and the excellent overview they provide.

We accept the consultants' argument that, because "the developing market could easily absorb double the rate of output (presently about 30 Ph.D.'s/year in Ontario) during the next five years" and because of the serious undersupply of qualified candidates, assigned quotas for the Ontario system would be meaningless.

We agree that adequate capacity and quality exists within the department and that decisions about specific research areas should be made within the individual universities. We accept the criticism that excessive effort has been devoted to "traditional and classical areas of research" and that our efforts should continue to be re-directed towards research more

agree that the relevance of the research work would be enhanced if support were made more dependent on contracts from high technology industry and appropriate federal government departments.

We intend to pursue our proposed five-year plan and strengthen our contacts with industrial and government laboratories. We will explore the possibility of establishing an industrial research institute (or an office of industrial research) since these institutes are noted as having a highly beneficial effect on the research of the faculty and graduate students.

We applaud the recommendation that a good Ph.D. programme should provide breadth by means of well balanced course work and depth by means of a thesis involving substantial research on a specific and topical engineering problem. Doctoral graduates from such a balanced educational programme will be able to move into industry and tackle problem solving on a broad front.

Conclusion

We hope that it will be clear from the foregoing that we find the reports generally quite acceptable and can endorse all their major conclusions and recommendations. We regard the specific points on which we disagree with the consultants to be minor in comparison to the aggregate of the issues on which we agree.

G. R. Love
November 12, 1973

FURTHER COMMENT FROM CARLETON UNIVERSITY

ON THE

ACAP ASSESSMENTS IN ENGINEERING

At the time of our response to the ACAP Assessments in Engineering, the Chemical Engineering report was not available and, while Chemical Engineering is not represented at Carleton, we held open the option to add further comments.

Again, we find ourselves in general agreement with this fifth report but we do not view the proposed Post-Entrance Acceptance Committee as a viable concept and will again state our willingness to support an evaluation scheme such as Carleton's scholastic index. As well, we would reiterate our former comments on critical size in rebuttal of the arbitrary minimum suggested by the Chemical Engineering consultants. Carleton supports the view of the Electrical consultants that quality outweighs quantity and the similar attitude of other consultants.

We would like to particularly note with approval the recommendation that students do their doctoral work at a University other than their undergraduate school.

RESPONSE OF McMASTER UNIVERSITY

TO

Ph.D. PLANNING ASSESSMENT IN CHEMICAL ENGINEERING

General

We commend the authors of this report for a comprehensive, useful and forthright analysis. There is clear and essentially unarguable perception of the total chemical engineering educational arena into which Ph.D. research activities must fit. The latter have been analyzed in terms of pedogogical content and philosophy, and a cogent overview given, supported most adequately by a detailed assessment of each institution. Concern has been shown for the role of the university, of an engineering faculty, and of a department - particularly as they contribute to and exercise their responsibilties within an industrial society. Equal concern for the individual professor and for the students is well expressed. We therefore find ourselves in basic agreement with the general approach taken, the emphases provided, and the dimensions of the assessment that have been drawn and used. This report of the consultants will continue to be valuable, therefore, for the setting it provides and the dynamics of chemical engineering science, of chemical engineering practice, and of chemical engineering research that are so clearly expounded.

It was clear that the consultants used extensively the detailed data provided for them by ACAP from the university submissions. Their utilization of these in combination with close examination during their visits produced a lengthy assessment of each institution. This assessment we consider to be excellent in its scope and detail. For planning purposes it will be most productive; for guidelines for continuing evaluation internally it will be very useful; and for maintaining our perspective in development and support of chemical engineering it will be of great advantage. Understandably, in view of the limited time, but nonetheless regrettably, the consultants did not use data for several years, nor evolve detailed estimates of rates of change of the important quality parameters. We are also sorry that their time at the individual institutions did not make it possible for them to examine in detail or give an evaluation of the content of courses or of the theses that have been produced. However, their overall assessments we consider to be of major importance and a most worthwhile contribution to each institution and hopefully to the collective system through the Discipline Group organization, CODE, ACAP and COU.

The consultants give detailed consideration to chemical engineering research topics and their categorization - an analysis which provides most useful insights and guidance. In their report, they identify as reasons for much of engineering research being centred in "engineering science" as:

- the need to publish in refereed journals,
- N.R.C. operating grant policies, and
- continuation of research from the professor's own Ph.D. work.

We would add two additional factors:

(i) mission-oriented problems have a deadline and require a solution much sooner than three years. The work must often by-pass fundamental questions in the rush for a solution;

(ii) apparatus for mission-oriented problems is often expensive and used only once. Most faculty members and Departments cannot afford this.

In summary, mission-oriented work is commonly contractually funded, relatively short-term and expensive and better done by postdoctoral fellows or other research associates who do not face the Ph.D. requirements. There is a very important and exciting role to be played by mission-oriented research as a seed for future longer-term Ph.D. studies to answer some of the fundamental questions by-passed by the short-term solution. Thus we consider fundamental engineering science research and mission-oriented research to be complementary, not exclusive of each other.

The consultants have given careful attention to the manpower problem, with a useful analysis of the flow into Ph.D. work, the part played in the Canadian scene by the Ontario universities, the time requirement for Ph.D. work, the ethnic origin of Ph.D. students, and Ph.D. employment information for recent years. We were pleased to note their willingness to critically examine "some of the forces underlying the reasons for the study", and agree with their analysis of the manpower situation and of the CEMC report, and with their rationale for not proposing quotas for each school or for the provincial pool. On the relevance of short term job market forecasts to the real need for Ph.D. chemical engineers, we fully support the consultants' view that no valid conclusions can be drawn therefrom (p. A-7, last paragraph, section 5.5, p. A-21, and section 7.2, p. A-42).

The consultants do not examine the fraction of the graduates of Canadian universities which would be needed to maintain a reasonable proportion in the Canadian graduate programs (section 6-8, p. A-27). A comparison of the required annual intake of new graduate students with the annual Bachelor's graduands in Canada would show that existing programs can be maintained at current levels only by accepting substantial numbers of students from abroad. We have always striven to accept students from as wide a range of backgrounds as possible so as to emphasize interaction and cross-fertilization of ideas, and to avoid accepting too many students from any one country or language group.

The emphasis of the consultants in their conclusions (on which they base their recommendations) that special roles, e.g. in graduate education, should have a proper place and not be circumvented by a quota or formula is one with which we strongly agree. Similarly, their conclusion that Ph.D. programs cannot and should not be subjected to overall numbers control based on demands of the market-place is one we too affirm. The consultants have also concluded in a commendably straightforward fashion that the Ontario system shows evidence of having more departments of Chemical Engineering than needs prescribe. Their rationale for this conclusion is well presented, and we would support their suggestion that the Ontario universities should give this matter the closest possible consideration.

Response to Specific Recommendations

Recommendation 1. We accept the concept that planning for the development of Ph.D. programs in engineering must include at an initial stage separate planning for the various individual branches including chemical engineering. However, we feel strongly that this separation cannot be arbitrarily done or carried out in an absolute sense, because many of the valuable interactive and joint responsibilities could be lost. Allowance must be made for real interaction, e.g. in such areas as in chemical and extractive metallurgy, in process control and optimization, and in heat transfer. The enfranchisement of a particular sector, which by tradition has been largely involved in a particular branch of engineering, would in our view be wrong. There must be, therefore, in any ultimate planning process, if indeed a suitable basis can be found, adequate allowance for a system or total approach to ensure that areas of joint or several interest are properly positioned.

Recommendation 2. We definitely concur.

Recommendation 3. We firmly agree with this recommendation as far as this University is concerned, and can accept the rationale provided by the consultants as a well argued case for any department of Chemical Engineering. The allowance of an occasional exception, and indeed the acceptance of recommendation 13, would acknowledge that some decoupling of research and Ph.D. activities could occur with little or no loss to undergraduate or Master's programs. We feel that the report does not make a convincing case against the possibility of a creditable program to the Master's level. Can one not conceive of an exciting program involving faculty members whose main source of new ideas arises through consulting and the practice of their profession? We would really prefer the statement by the consultants on page A-1 that excellence in undergraduate engineering education can be maintained only if strong graduate research programs exist.

Recommendation 4. Again, we concur in a broad sense since no time scale is indicated. We appreciate and support the implication that many factors must reach a satisfactory level before a good Ph.D. program can be mounted; and we consider that this report does in its totality give a relatively clear picture of what the consultants consider that level to be.

Recommendation 5. We agree and support strongly. We note further that the acceptance in toto of the forecasts by departments (including the numeric interpretation by the consultants for the University of Toronto) is explicit recognition by the consultants of the capabilities of each department for maintaining Ph.D. studies, subject presumably to a size limitation as in recommendation 13. It would be assumed, in our view, that the implication is also present that modest upward revision of such forecasts is not precluded in the future.

Recommendation 6. Again, we agree. We share the concern of the consultants for the relatively small number of Canadian university Bachelor's graduates enrolling for Ph.D. work. We would strongly support any efforts to develop a concerted approach that will clarify to many more students the value of their completing some graduate work.

Recommendation 7. There is not a clear definition of "entrepreneurship" so that it is difficult to assess this recommendation. We wonder whether a university environment is suited to developing entrepreneurship in the sense of undertaking new economic enterprises.

A faculty member who has his own business will inevitably face conflicts between the demands of that business and those of the university. Occasionally one or the other may suffer from neglect.

We strongly believe that Ph.D. students should be guided in developing entrepreneurship in the sense of being willing to undertake any problem, to be confident of their ability to find a solution, and to accept the risks of failure. We feel that this can best be developed through dynamic leadership, demonstrated by professors in their respective research programs.

Recommendation 8. We agree but would in practice normally require an A level or high B (first class or upper second class). At the same time, special circumstances, such as when research experience in government or industry may well offset certain earlier academic deficiencies, should be allowed to be taken into account.

Recommendation 9. We find this an interesting recommendation and certainly the future embarrassment of having to reveal the admission of an unqualified student would be a potent deterrent. There would be some honest disagreement on the standards of foreign universities. We comment further that the consultants elsewhere (page A-14) have emphasized that the entrance screening process is "quite selective and great care is taken to accept only those students with proven scholastic achievements". While the question arises as to the real necessity for a new review structure for a system that apparently operates well, we would support the proposal of the Discipline Group (Chemical Engineering Department Chairmen) assuming the review role specified, including full disclosure on individual cases.

We are firmly convinced that it would be most unwise to invite COU to pass directly on the entrance standards of individuals into Ph.D. programs. This would constitute an abdication of some of the academic function and responsibility of departments and Faculties within individual institutions. In the same light, we cannot accept, of course, any move that would involve provincial authorities in applying their overall financial authority and responsibility to do so through individual cases.

Recommendation 10. We fully agree that it is in the student's own best interests that he take the Ph.D. degree at a different university from the one at which he obtained the first degree, and would welcome measures to encourage this mobility, while retaining full freedom of choice for the student.

Recommendation 11. We would emphasize that it is our policy precisely to support the grouping and concerting of research. In our view, the most stimulating environment for students requires that groups not be too rigidly delineated, since we see real value in interaction among faculty and students in different groups. Indeed, we believe that groups should be flexible and often overlapping so that new ways of combining areas of expertise will arise more easily.

Recommendation 12. The basis upon which our Department of Chemical Engineering was built was that all members of faculty would participate fully both in graduate teaching and research and in undergraduate teaching. Indeed, we believe that those who are the best teachers should be encouraged to contribute fully to the graduate program rather than

leave graduate education to those whose inclination is to do research rather than to educate. At the same time, our University policy is such that in individual cases for both promotion considerations and salary review, special weight can be attached to the contributions to teaching, as compared to those in research.

Recommendation 13. We would agree that a program with fewer than ten Ph.D. students on the average should be re-examined after five years. Temporary suppression of a Ph.D. program would tend to lead to permanent suspension unless strong steps were taken by the university in question to retain its best faculty members. This could be achieved by financial encouragement of other forms of research, such as postdoctoral fellowships. Thus temporary suppression of a Ph.D. program would be irreversible unless great care is exercised.

Recommendation 14. If the University of Toronto agrees with this recommendation, we would welcome the increased interchange which would result. We believe that all universities should advise their students to take their Ph.D. degrees at a different university from their Bachelor's degrees.

Recommendations 15 to 17. These concern other universities.

Responses to Comments on McMaster University (Section 8)

The consultants' evaluation of the Department of Chemical Engineering, McMaster University, provides a valued judgment of our efforts.

Through our own omission, we failed to discuss plans "to maintain faculty vitality during a period of equilibrium of faculty members" (A-46, above section 8-4). While the consultants did not question members of the Department on this matter, we have indeed given some thought to measures to maintain faculty vitality.

McMaster University has an established sabbatical leave policy, of which every member of the Department of Chemical Engineering has taken advantage, when eligible. We have had and encourage visits by faculty members from other universities for various periods of time and would like to have similar visits by engineers from industry. Members of the Department have in the past spent time in industry and we feel that these contacts should be more strongly encouraged in the future. Furthermore, we have tried as much as possible to rotate faculty members in undergraduate teaching assignments so as to encourage new ideas in existing courses. The rotating chairmanship also provides a different brand of leadership every three years, in order that no one faculty member establish an indelible imprint on the Department. We also encourage interaction by members of the Department with faculty members and students from other disciplines as a means of stimulus.

There are some corrections of data and facts we wish to record.

Table 6.1.2, p. A-24: Research funds.

It is unfortunate that the data listed for McMaster in this table are incorrect and incomplete. The fault lies partly with the curricula vitae forms which did not specify the form of data required, partly with us in not correcting the mistaken data thence extracted,

and partly with the consultants not incorporating the correct data supplied to them in person during their visit to McMaster.

The correct data for McMaster for 1972-73 are:

	Correct	Shown in Table 6.1.2
N.R.C. Operating Grants	$143,340	$112,440
Computing Grants	13,300	-
Equipment Grants	18,211	-
	174,851	112,440
Other Canadian Granting Agencies		
Dept. of Supply & Services	13,000	-
Polysar Ltd.	5,000	-
Ont. Dept. of Environment	4,238	-
Environment Canada (Water Management)	125,000	-
	147,238	
Grand Total	$322,089	$112,440.

Grand Total excluding N.R.C. computer and equipment grants: $290,578
Number of faculty members able to apply for any grant in 1972-73: 15
Number of faculty members receiving N.R.C. operating grants: 14 (93%)
Number of faculty members receiving a grant: 15 (100%)
Average grant per faculty member: $21,472 including all grants,
19,372 excluding N.R.C. equipment and computer grants.

A-44 , paragraph 3, line 1

In fact, three faculty members are over 43 years of age: Drs. Shemilt, Hodgins and Anderson.

A-45 , paragraph 1

The statement on average NRC/DRB/MRS grants per faculty member may well be based on incorrect data since Table 6.1.2 contains the only explicit data shown but it is certainly incorrect for McMaster.

Table 6.12, p. A-33

The entry for McMaster under "Staff Size" should be 15 instead of 14.

January, 1974

C-17

UNIVERSITÉ D'OTTAWA
550, RUE CUMBERLAND

OTTAWA, ONTARIO
Canada K1N 6N5

UNIVERSITY OF OTTAWA
550 CUMBERLAND STREET

CABINET DU RECTEUR

OFFICE OF THE RECTOR

December 21, 1973

Dr. M.A. Preston,
Executive Vice-Chairman,
Advisory Committee on Academic Planning,
Ontario Council on Graduate Studies,
Council of Ontario Universities.

Dear Dr. Preston,

This is a response to your request for comments on the A.C.A.P. report on graduate studies in Chemical Engineering.

In general we are pleased with the report and submit only the following comments concerning specific recommendations 9 and 13 on page A-10 of the report.

Recommendation 9: We see more disadvantages than advantages in the establishment of a Post-Entrance Acceptance Committee. It could well lead to problems between different Chemical Engineering Departments of Ontario. At the University of Ottawa the admission of all graduate students must be approved by the Graduate School. Our Department of Chemical Engineering has never attempted to persuade the Graduate School to admit a candidate with a below B record. In addition, applicants for the Ph.D. program are also screened by the joint Admissions Committee of the Engineering departments.

Recommendation 13: The recommendation that an average ambient population of at least ten Ph.D. students be maintained is not necessarily a guarantee of a good Ph.D. program. It seems to us that the number of students is of minor importance and that the maintenance of a scholarly research environment is essential. Regular course work offerings at suitable levels, opportunities of interaction between various disciplines, provision of adequate research facilities, motivations and interests of the staff members, the presence of post-doctoral fellows, the recognition by the Administration of the need and importance of a strong graduate program, are some of the major factors in providing a desirable atmosphere for the training of graduate students.

Yours sincerely,

Roger Guindon

Roger Guindon, O.M.I.,
Rector.

QUEEN'S UNIVERSITY
KINGSTON, ONTARIO
SCHOOL OF GRADUATE STUDIES AND RESEARCH

January 14, 1974

Dr. M. A. Preston
Executive Vice-Chairman
Advisory Committee on Academic Planning
Council of Ontario Universities
130 St. George Street
Suite 8039
Toronto, Ontario M5S 2T4

Dear Mel,

Although late in doing so, I should like to submit Queen's response to the ACAP Consultant's report on Chemical Engineering.

a) There is some disagreement with recommendation 1, because the Faculty is a professional Faculty and the Dean must plan for it as a whole. On the other hand, the disciplines do welcome advice on their individual situations.

b) We support recommendations 2 to 8 inclusive.

c) In connection with recommendation 9 we comment as follows. The Chemical Engineering Discipline Group has an informal agreement to review admissions annually. This is intended as a means of exchanging information, and as an opportunity to exercise moral suasion by review and discussion within the group. This we feel to be prudent and practical. However, the extension to post facto budget review is unlikely to be practical, given the Ontario system of financing universities. It is unacceptable.

d) We agree with the intent of recommendation 10.

e) Concerning recommendation 11 we agree that it is stimulating for students and staff to have contact with others who have similar interests. However we feel that the group of people with shared interests can work effectively between departments as well as within departments, and that the contact should also exist between universities, and between university and industry. Therefore individual departments should not be constrained to have group research within the department.

f) We agree with the first part of recommendation 12 but would regard any licensing procedure as quite undesirable. With respect to

the second part of the recommendation, Queen's University has a statement of policy which acknowledges that a staff member's contribution may shift in emphasis from one area to another throughout his career. The statement reads in part as follows. "The nature and extent of each faculty member's endeavours are matters to be agreed upon with the University. These professional endeavours - in total comprising some combination of teaching, supervision, research, scholarship, professional service or consultative work, and administration - may vary from time to time for any individual and may differ among individuals." It is important to recognize that this process includes the potential for reversible changes in emphasis. For example, a staff member may find it necessary to emphasize administration rather than research for a period of time. Then the emphasis may be reversed, to the benefit of the university and the staff member.

g) With respect to recommendation 13, this is clearly an important one for the Queen's department since recommendation 16 refers to Queen's University and specifically refers back to recommendation 13. It is the intention and expectation of the department that we will maintain an average ambient population of at least 10 Ph.D. students of the required calibre. In the past we have insisted on the maintenance of standards, and will continue to do so in the future. We have also stressed the desirability of having a high proportion of Canadian students. This has resulted in a small graduate enrolment with a slow rate of growth. However it has produced the quality and the environment which we wished to achieve, and which we hope to maintain. We hope that any future review of a department's Ph.D. program will continue to be concerned with the quality of the performance, and will not ultimately depend upon the number of Ph.D. students present. We do not understand how the number of 10 Ph.D. candidates per year was arrived at. A smaller number could still ensure the preservation of high standards.

Comments on the Section on Queen's University (Section 10)

The report is a fair and accurate assessment of the Department's Ph.D. program. We are aware of the weaknesses pointed out by the Consultants and have been taking steps to improve in these areas. On the other hand, we are encouraged by several of the Consultants' comments, for example by the view that "the Department's goals and future research activities will be responsive to the prevailing needs of the Province".

There is only one point which requires further comment. In section 10.6.2, the report states that it should be a cause of some concern

to us that we have retained a number of our own graduates. We feel that it should be recognized that Queen's has a large undergraduate program and that we have provided graduate students for other Chemical Engineering Departments in Canada, regularly, and probably in larger numbers than any other Canadian University. We are not concerned that some of our graduates wish to stay at Queen's, however we share the Consultants' concern that we have not attracted an equal number of qualified students from other Canadian Universities. This is a general concern among Ontario Departments.

Yours sincerely,

Bob

R. McIntosh
Dean
School of Graduate Studies and Research

RM/mb

UNIVERSITY OF TORONTO
School of Graduate Studies

OFFICE OF THE DEAN

Toronto 5, Canada

January 3rd, 1974.

Dr. M. A. Preston,
Executive Vice-Chairman,
Advisory Committee on Academic Planning,
Council of Ontario Universities,
130 St. George Street, Suite 8039,
Toronto, M5S 2T4.

Dear Dr. Preston,

The University of Toronto finds the report of the consultants on the Chemical Engineering Planning Assessment to be on the whole a useful document. It is all the more regrettable, therefore, that the report leaves a number of unnecessary misapprehensions about the Department of Chemical Engineering in this university and that the consultants contradict within the body of the report some of their own recommendations.

Firstly, we wish to make the following response to the recommendations contained in the report (numbered as on pp. A - 9 to A - 11):

1. While we agree with this recommendation, we would note here that each university has the right to respond to the engineering assessment reports seen as a group and that it may be advisable to make some general recommendations concerning engineering as a whole.

2. We agree.

3. We agree.

4. Again we agree, on condition that any doctoral program established be of high quality and that the university proposing such a program be prepared to make the necessary resource investment to ensure that quality.

5. We agree with the recommendation that no reduction should be made in Ph.D. student population. In fact, the market for persons holding the doctoral degree in Chemical Engineering may well require an increase in the number of candidates starting the doctoral program now.

6. While it is desirable to increase the number of Canadian Ph.D. candidates registered in Chemical Engineering, the problem probably cannot be solved by ordinary transfer of information. Efforts can be made in two directions; firstly, through the development of professional contacts between academics and potential Ph.D. employers in industry

6. cont'd....

and government; secondly, back through the education system, perhaps as early as high school.

7. We endorse this recommendation and we believe that the Department of Chemical Engineering of this university already meets its objectives. We understand entrepreneurship to include skill at innovation, enterprise, and effective operational design, as well as an appreciation of the realities of public policy and of the market. The understanding and development of such skills can be aided by a small but active involvement of Ph.D. directing staff in industrial Chemical Engineering practice. Consequently, it seems odd that the department in this university is subject to criticism in the body of the report for their successful use of this approach.

8. The standard seems unnecessarily low and we trust it will not be taken to suggest we admit students who only meet the minimum B level.

9. Although a common standard of admission may be desirable in this case, we strongly oppose the imposition of financial sanctions against institutions in the system. An earned and known reputation of poor quality would serve as sufficient sanction.

10. We are agreed that mobility is often desirable and beneficial, providing it does not prevent a student from attending the university of his choice. We strongly oppose any financial incentives to encourage mobility. These could too easily become financial penalties.

11. We are in general agreement with the concept of the association of research workers to form co-operative groups both within the department and between departments when such groups are required by the problem in hand. We are sensitive, however, to the primary requirement for the development of the students' potentialities, and we distinguish this requirement from the purely research oriented objective. We do not agree that team research is always a good basis for the best growth and development of the doctoral student.

12. We agree.

13. While realising the benefits of critical size for a group of doctoral students in many disciplines, we do not see anywhere in this report a case presented for Chemical Engineering.

14. We agree in principle with this recommendation. The Department does, in fact, recommend to its students that they consider proceeding with graduate work at universities other than Toronto and will continue with its efforts to facilitate the reciprocal movements of students among Ontario graduate schools.

15. We agree with the reference to recommendation 11, subject to the conditions noted there. With regard to the question of seminars, we accept the need for improvement in this area. It has been the subject of discussions with graduate students within the past few months. The department has already agreed to institute a new and more formal seminar format on a trial basis.

    Graduate courses were widely discussed among faculty and students last year. The number of graduate courses now being given appears to offer the student a reasonably wide choice. We attach a list of the courses actually being given in the fall term, 1973, and the offerings for the spring term, 1974. This list does not include a number of upper-level undergraduate courses which may also be taken by graduate students. Over a two-year period a total of 50 different graduate (excluding undergraduate) term courses is available to the 45 full-time doctoral students in the department. Because of the need to provide courses for part-time students, particularly in the M.Eng. program, and because of financial constraints, some of these courses are offered in the evening. No doubt this is sometimes inconvenient to some persons, but there is often no economic alternative if we are to meet our responsibilities to part-time students.

Within the body of the report, reference is made to the engineering library. We agree this is not as good in its chemical engineering holdings as the municipal library, which is the best of its kind in Canada. Since the municipal library is closer to the department than is the faculty library, we see no reason why students should not benefit from it. The consultants recognise the problems created by relatively old housing and shop facilities and that the current renovations should generally improve working conditions for staff and students.

The consultants remark that little interdepartmental co-operation is visible at this University. This is not borne out by evidence submitted to us by the department. As of November 1973, there were 10 members of the department involved in 17 co-operative programs or supervisions with other science and non-engineering departments. This excludes co-operative work within the Faculty of Applied Science and Engineering.

Finally, we regret the attitude taken by the consultants on consulting by the staff in chemical engineering, since the report leaves a false impression of their activity in this sphere. Strangely, the account of this activity seems to contradict recommendation 7, which deplores the lack of entrepreneurship in students in this discipline, as well as recommendations of most other engineering assessments. Attached is a report of the number of consulting days spent by the faculty for the academic year 1972/73 where it will be noted that the faculty average is 12 days a year,

or one day a month for each professor, which hardly seems excessive for this field. It is, in fact, the average for other major departments in the Faculty here.

Yours sincerely,

A. E. Safarian

AES/jd/
Encl.

A. E. Safarian,
Dean.

Graduate Courses Being Given by the Department of Chemical Engineering in the Fall Term - 1973.

1105X	Momentum, Heat and Mass Transfer I
1108X	Process Fluid Mechanics and Heat Transfer
1109X	Process Modelling and Simulation and Control
1110X	Topics in Heat Transfer
1111X	Optimal Process Control
1117X	Topics in Applied Chemical Thermodynamics
1120X	Dynamic Planning of Industrial Enterprises
1122X	Biochemical Engineering I
1202X	Instrumental Methods of Chemical Analysis I
1302X	Principles of Polymerization
1307X	Ceramics II
1401X	Air Pollution Chemistry and Engineering
1404X	Environmental Radiochemistry
1501X	Nuclear Reactor Fundamentals
1503X	Nuclear Instrumentation and Measurement
1510X	Nuclear Reactor Design
1514X	Nuclear Reactor Safety Analysis

Graduate Courses Expected to be Given by the Department of Chemical Engineering in the Spring Term - 1973.

1106X	Momentum, Heat and Mass Transfer II
1107X	Applied Mathematics for Chemical Engineers
1112X	Advanced Topics in Optical Control
1116X	Chemical Reactors
1119X	Pulp and Paper Chemistry Technology and Engineering
1124X	Topics in Heat Transfer II
1203X	Instrumental Methods of Chemical Analysis II
1301X	Advanced Polymer Engineering
1305X	Strong Solids
1306X	Ceramics I
1309X	Plastics Engineering
1402X	Water Pollution Chemistry and Engineering
1502X	Neutron and Photon Transport
1504X	Nuclear Chemistry
1507X	Thermal Aspects of the Nuclear Reactor
1511X	Nuclear Reactor Control Systems
1512X	Nuclear Reactor Materials
1515X	Nuclear Reactor Containment

Statement of distribution of consulting work of full-time professorial staff in the Department of Chemical Engineering during the year July 1, 1972 - June 30, 1973.

A total of 345 days of consulting work was distributed among 28 professors during the year July 1, 1972 to June 30, 1973 as follows.

Consulting activity (days)	Number of professors
0	7
1-10	7
11-20	7
21-30	5
31-40	2

The average commitment to consulting was, therefore, approximately 12 days per professor in the department over the complete year, i.e. inclusive of the summer months. This is roughly 1 day/month per professor.

December 4, 1973

SEMINARS IN THE DEPARTMENT OF CHEMICAL ENGINEERING

During the years 1967-68 to 1971-72, approximately 12 seminars/yr supported by the School of Graduate Studies were given in the Department. Subsequently, budget cuts have led to reductions in the frequency of such seminars to 6/yr. In addition, many interdepartmental seminars have been given in recent years involving topics in materials and polymer science, nuclear engineering and environmental issues.

In the present academic year, there have been four seminars sponsored by the Graduate School, several interdepartmental seminars, and the series of Centennial lectures organized by the Faculty.

As elsewhere, attendance at seminars has tended to decrease despite the high calibre of the speakers, a fact that led to fewer seminars being scheduled in the last year or two.

However, plans have already been made to hold a series of eight seminars in the spring term of 1974. There will be six presentations by doctoral candidates nearing the completion of their studies and two presentations by invited speakers supported by the Graduate School.

Response of the University of Waterloo to the Report of the Chemical Engineering Consultants to the Advisory Committee on Academic Planning submitted to ACAP, December 20th, 1973

The report of the Chemical Engineering consultants is one of the best of the reports devoted to the planning study of doctoral work in engineering. The University of Waterloo wishes to commend the consultants for the fine job which they have done. We will make a few general comments on the report below, comment specifically on sections of the report that are devoted to the programme at this university and finally state our position on the recommendations which the consultants have set forth in the report.

General Comments:

The report presents a very good outline of the scope of chemical engineering and of the general objectives which should guide the development of a Ph.D. programme in chemical engineering. The consultants also discuss the difference between chemical engineering and chemical engineering science. They suggest that there is room in the Ontario system for more activity in applied research and development. We support this suggestion but if this is to be achieved there must be greater financial support available for this type of research activity. At the present time the granting agencies lean heavily towards the support of more scientifically oriented research.

The report also presents a careful and thoughtful analysis of the job market and the need for doctoral programmes in chemical engineering. We support the consultants in their position that this is the wrong time to be curtailing graduate enrollment in this field. Indeed events which have taken place since the report was written and which see us now in the midst of an energy crisis make this recommendation even more important. No one can really foresee the need for highly trained manpower and the length of time that is involved in producing doctoral graduates requires that changes be made slowly and only after the most careful kind of study. There is no evidence as far as we are concerned of a job shortage in this field at the present time and no prospect of one in the future. All of our recent Ph.D. graduates in chemical engineering have found meaningful employment.

We share the concern expressed by the consultants about the small number of Canadian students who choose to do graduate work in chemical engineering. As we have pointed out in our responses to the other engineering reports, this is a problem that is common to all of engineering. The University of Waterloo has made every effort to attract qualified Canadian students and will continue to do so. Other consultants have suggested the need to increase the level of financial support for graduate students and we have supported this recommendation. What is probably more important, however, is to bring about a change in the general atmosphere surrounding doctoral work in engineering in this country and to convince the brightest young Canadian students that there are challenging opportunities for advanced work in Canadian industry. In the meantime we will continue to screen the foreign students who are taken into our programme to ensure that only students of the highest calibre are brought into the country.

Specific Comments:

We have only one relatively minor comment to make on the section devoted to the University of Waterloo. On Page A-72 Section 12.11 the consultants state that the main function of the Graduate Council "was stated to be the screening of Ph.D. thesis committees and external examiners." This activity is part of the function of the Faculty of Engineering Graduate Studies Committee, not of the Graduate Council. The Graduate Council is a university wide body which advises the Senate on matters of policy in the area of graduate studies. The Faculty of Engineering Graduate Studies Committee plays a much more direct role in the organization and administration of graduate work in the faculty.

Comments on Recommendations:

The consultants make seventeen (17) recommendations in this report. The University of Waterloo generally supports the recommendations which pertain to the entire provincial system subject to the comments which we will make below. We make no comment on those recommendations which pertain to the programmes at other universities.

Recommendations 3 and 4: We support the contention of the consultants that a Ph.D. programme must be regarded as an integral part of the total educational process in chemical engineering. It follows from the acceptance of this principle that universities offering programmes in chemical engineering should have work at all three degree levels - bachelor's, master's and doctor's. It should not be inferred from this, however, that simply because a university has a bachelor's programme it automatically should expect to offer doctoral work. Rather the reverse should be the case. It is important in our view that doctoral work be of high quality. Only then will the impact on the educational process at the undergraduate level be effective. If a university is unable to maintain a strong doctoral programme then one might question its ability to sustain high quality bachelor's and master's work.

Recommendation 8: We support this recommendation. A "B" average is a minimum requirement for admission to graduate work at the University of Waterloo. However, this cannot be interpreted rigidly. The university must be able to exercise some discretion particularly in the admission of mature students who have had experience in industry beyond their normal undergraduate training. In these cases, recommendations from supervisors may be more meaningful as an indication of the student's aptitude for advanced work than his undergraduate record which may be several years old.

Recommendation 9: We support the suggestion that graduate admissions be screened, but we believe that this should be the responsibility of the discipline group. There is no need in our view to establish a separate committee to carry this out. We do not support the suggestion in this recommendation that B.I.U. income not be given for low quality students. This would be far too difficult to control. We believe that if the screening function is carried out by the discipline group the pressure on the universities will be such as to minimize any problems.

Recommendation 10: We support this recommendation in principle but not in detail. We believe that students should indeed be encouraged to not take all three degrees at the same institution but we do not believe that it is practical or desirable to have any rigid legislation preventing this. In some cases there may be valid reasons why the student should stay at the same university.

Recommendation 12: We support the first part of this recommendation that Ph.D. programmes should be the responsibility of those staff who have a satisfactory record of research and supervision. We are uncertain however as to the intention of the second part. It would seem to us to be up to each university to establish the criteria by which it judges its faculty. The University of Waterloo already has published policies on promotion and tenure which set forth the criteria used at this university.

Recommendation 17: We cannot accept the last paragraph in this recommendation. We do not believe that faculty members at one university are the responsibility of the Ontario university system. Each university must be free to select its own faculty. We cannot accept an obligation to hire professors from other universities whose programmes in certain disciplines might be curtailed or phased out. At the same time we would not expect other universities in the system to assume any such obligation for the members of our faculty.

University of Western Ontario Response to the Consultants Report - Ph.D. Planning Assessment in Chemical Engineering

December 12, 1973.

This response has been prepared by a Committee of Senate charged with generating such a response to the ACAP Consultants' report on doctoral studies in Chemical Engineering. Our comments are divided into two categories - those dealing with broad questions of academic policy and those dealing with factual details.

Policy Matters

1. Recommendation #9 on pg. A-10 deals with the creation of a system-wide committee to monitor graduate admissions with a view to ensuring that minimum admission requirements are maintained in all programs. Because admission standards provide one measure of program quality, we are in complete agreement with this recommendation and can foresee the already established Discipline Group fulfilling this function on a continuing basis. We are, however, strongly opposed to the enforcement of admission requirements through the use of financial sanctions as recommended by the Consultants. In view of the fact that all admissions to Chemical Engineering graduate programs are already carefully scrutinized by the Faculty of Graduate Studies, the moral suasion which will result from system-wide disclosure should be sufficient to accomplish the objective and more in keeping with a proper University-Government relationship.

2. Recommendation #13 on pg. A-10 introduces a new approach to the critical size concept, this time in terms of an average ambient population. It is our view that "critical capability" is more germane to a Ph.D. program than "average ambient population", and that the number of 10 Ph.D. students appears somewhat arbitrary. If it is critical capability which is the concern, then the number of post-doctoral fellows associated with a research program must obviously be taken into account.

3. We share the concerns of the Consultants outlined on pg. A-40 dealing with the low proportion of Canadian students in Ontario graduate programs. If the Chemical Engineering graduate programs in Ontario are to compete with the financial attractions of industry for the intellectual interests of Canadian bachelors graduates in Engineering, then more attractive scholarship programs aimed at Canadian students are absolutely essential. In responses to some of the other Engineering ACAP Consultants Reports where the low proportion of Canadian students in graduate programs has been identified as a problem, we have suggested the solution of higher stipends for graduate students holding professional qualifications, as is presently done in the fields of medical research.

Factual Details

1. Three of the entries for Western in Table 6.1.1 on pg. A-23 are incorrect and should be changed. The entry for F.T. Staff should read 10 rather than 11, for Assistant Professors should read 2 rather than 3, and for Postdoctoral Fellows should read 11 (eleven) rather than 0 (zero). As a result of these changes, Table 6.1.2 on pg. A-24 will have to be modified to show $12,350 as the average total grant per professor ($123,500 divided by 10 professors).

2. The indication that a student in Engineering received more than the allowable $2,400. of formula support per three consecutive terms is an exceptional instance. Recently instituted continuous monitoring of support to students in the Faculty of Engineering would indicate that a limited number of minor deviations from regulations have occurred in the past and steps have been taken to correct the overcommitment within the budget year under consideration. These actions have assured that even small deviations from Provincial policy do not occur.

A Response of the University of Western Ontario to the Advisory Committee on Academic Planning with respect to the Engineering Specialty Assessments (1973).

November 29, 1973

storical Aspects

Approximately 20 years ago (1954) on the recommendation of the Faculty Arts and Science the Senate of the University of Western Ontario established a partment of Engineering Science. This Department undertook to gather the faculty cessary to establish an independent Faculty of Engineering Science and Faculty atus was granted to this group in 1960. The beginning of formal graduate study s the offering of an M.E.Sc. program which received the approval of the Faculty Graduate Studies and Senate in 1961. The first candidates (4) were admitted in ptember 1962 and by 1964-65 the number of M.E.Sc. candidates had risen to 18. October 1964 the Faculty of Graduate Studies approved the establishment of a Ph.D. ogram in Engineering Science and the Senate supported this action on January 29, 1965. om the outset an effort was made to emphasise the interdisciplinary nature of the ogram and graduate training was offered in a limited number of areas which at that me included chemical and biochemical engineering, soil mechanics, structural gineering and thermodynamics. Since its inception the Ph.D. program has produced number of graduates

1969	-	1
1970	-	1
1971	-	6
1972	-	6
1973	-	6

In 1973-74 there were enrolled in the Ph.D. program 29 full-time students d 15 part-time students. All of these students have received or are enrolled in ograms leading to a Ph.D. in Engineering Science and none of them has received degree designated as serving one of the traditional specialties of engineering .g. chemical, mechanical, etc.).

The "Ring of Iron" published in 1970, among other things, recommended at the Faculty of Engineering Science drop the "Science" from its name (Ring of Iron, 77). The Faculty, after considering this matter, elected to retain this name as did its interdisciplinary programs. The "Ring of Iron" did recognise the inter-sciplinary nature of the programs by recommending that Western "concentrate" on vironmental engineering which was acknowledged at that time to be a foretaste of the ture. At that assessment it was also noted that "Western has gained distinction with s work in industrial aerodynamics, electrostatics and bioengineering". (Ring of Iron, 76).

esent Assessment

As a consequence of dissatisfaction with the stringency of Ph.D. recommend-ions in the "Ring of Iron" as adopted by the Council of Ontario Universities, the uncil of Deans of Engineering has sought a reassessment of the Ph.D. programs in tario Engineering Schools. This task was undertaken under the aegis of the visory Committee on Academic Planning and something which has been erroneously rmed a "mini-appraisal" has been performed.

The conditions under which this appraisal was undertaken are of particular interest because the form which this assessment has taken fails to take cognizance of work of an interdisciplinary nature which may be deemed to be outside the traditional specialties of civil, electrical, mechanical, chemical and metallurgical and materials sicence engineering. Examination of the five reports which have been received reveals rather remarkable differences between reports in spite of the fact that the consultants seem to have been given substantially equivalent instructions (with the possible exceptions of mechanical and chemical groups who do not specifically report their terms of reference). Remarkable perhaps are the prevalent comments about "critical size" when the printed terms of reference contain no mention of critical size.

As the present assessment has been conducted, it seeks to determine whether the engineering schools of the province contain five individually certifiable traditional specialties of engineering. If this was the objective of the assessment it was not so stated in advance. Not surprisingly, the large schools with substantial groups in each of the specialties survive assessments of this sort. The smaller schools regardless of the quality of their operations when judged in this particular frame of reference are found wanting in one or more of the traditional specialties. That is not to say that the discipline is not represented in the school since it must be to meet undergraduate instructional needs but the group practising the specialty is small and does not meet some arbitrarily defined critical size.

What can a school that is faced with this difficulty do? Aside from the obvious and in general unacceptable possibility of retiring from competition the researcher in the small "sub-critical" groups seeks to meet the need for interaction with other professionals and to develop his own intellectual pursuits by developing liasons with other individuals in related fields. The consequence is that individuals with different backgrounds, information and skills address themselves to problems which they have in common. At its best this kind of development can be the most exciting research conceivable. At its worst the products of the activity may be minimal or zero. However, we would contend that operations of this sort which stem from small interdisciplinary groups are potentially of great importance and furthermore, that the present assessments carried out along stereotyped lines may not detect these activities and are likely not suited to the evaluation of them.

It will be evident that interactions with individuals in other disciplinary specialties, however integral to the research in hand, will not permit the specialist group sparsely represented on staff to meet the criterion of critical size when the assessment is carried out in the framework of traditional disciplines.

The situations which prevail at Western in which these difficulties of assessment are most easily identifiable lie with the Electrical and Materials Science groups although the prevailing interdisciplinary attitude of faculty members in other groups leads to a reduction in the vertical integrity of the traditional specialties and to an enhancement of horizontal interactions between specialties. Encouragement of this horizontal interaction has been a conscious policy within the Faculty of Engineering Science and is a major determining factor in the decision of the Faculty to offer an Engineering Science program rather than programs in the traditional specialties.

The Engineering Science Concept

The absence of departmental structure and all that it contributes to specialty tribalism, the limited dimensions of the Faculty (approximately 43 F.T.E.), and the existence of congenial relations has led to development of extensive interaction and collaboration between groups within the Faculty. For similar reasons it has also been possible to develop interfaculty research activities in the biomedical area, (collaborative activities in both biomedical engineering and applied physiology), in radioscience (as participating members in the Centre for Radioscience) and in computer science (where the systems engineering group has developed a collaboration). The abiding interest of the Faculty in environmental matters has promoted interaction with other parts of the University which may be expected to bear fruit in the future. It should be noted that in all five of the assessment reports the comments on the quality of the work in hand were favorable.

In effect, circumstances have dictated that a particular course of development be followed. It would be our contention that this course has led to much that is valuable and worthy of development. While the route we pursue may be inappropriate to other Engineering Schools we would request that we be judged in this framework and not in the traditional format which cuts across rather than displays our most effective activities.

These remarks may be concluded by a statement that as recently as November 14, 1973 and with the full knowledge of the various consultants reports, the Faculty of Engineering Science reaffirmed its intent to continue to offer undergraduate, masters and doctoral training in Engineering Science and not in any of the specific sub-disciplines.

RESPONSE OF THE UNIVERSITY OF WINDSOR TO THE ACAP REPORT FOR DOCTORAL STUDIES IN CHEMICAL ENGINEERING

Introduction

The consultants' report on Chemical Engineering at Windsor is generally complimentary. However, it applies two considerations in singling out Windsor for further investigation. These are that there are too many departments of chemical engineering in Ontario and that a critical size exists for viable operation of a department. These considerations are examined in detail as we comment on the report's recommendations in turn.

Since one table of data (6.1.2) is completely erroneous with respect to at least Windsor we also provide a set of correct data. Also attached is a brief description of the operation of the Engineering Process Design Division, the means by which Windsor achieves critical interaction.

Recommendation 1. That, if indeed a suitable basis for planning the development of Ph.D. programs in Ontario Universities were found, such planning should be done separately for the various individual branches of engineering (e.g.: chemical, civil, etc.) rather than for engineering as a whole;

This we reject on the basis that it ignores the necessity and the desirability of interaction between departments (and disciplines) at individual schools. Such interdisciplinary interaction may be even stronger than intra-disciplinary communication between various universities. In most instances the separate departments of engineering were set up with the objective of developing strong overall faculties of engineering. This has been the intent at Windsor.

Recommendation 2. That, considering the length of time required to establish a high-quality Ph.D. program, no short-term considerations should be involved in any planning;

We agree. And long-term considerations should be completely thought out.

Recommendation 3. That the Ph.D. program be regarded as an integral part of the total educational process in chemical engineering, and by its presence strongly influencing programs at other levels in a given university;

Agreed. The statement, however, holds for any learning discipline, not just chemical engineering. Therefore, each individual department of engineering need not give its own particular Ph.D. to achieve the above. A sharing of such a program between small departments of like background may in fact be better than having departments of limited resources competing, rather than working, with one another.

Recommendation 4. That no university having a Bachelor's and a Master's program be prevented permanently from offering a doctoral program;

The intent is presumably that no qualified individual be prevented permanently from having doctoral students under his supervision. See 3 above.

Recommendation 5. That because no evidence of major overproduction of Ph.D.'s in chemical engineering in Ontario exists, the total population of Ph.D. students in the Province as forecast and desired by the departments not be reduced significantly during the next five years.

We agree. Enough reduction has already taken place in any case.

Recommendation 6. That, considering the decreasing numbers of Canadians registering in Ph.D. programs in chemical engineering, appropriate steps be taken to inform:

1) potential candidates of the value of a Ph.D. degree in many phases of Government and industrial activities, and not only in research and development;

2) employers, both in Government and industry of the premium value of the chemical engineer with a Ph.D. in many phases of their activities in addition to research and development;

Agree. The Ph.D. program has lost its Canadian identity and must do something before becoming suspect.

Recommendation 7. That Ph.D. programs in addition to the usual scholarly goals, have as one of their aims an effort to develop entrepreneurship in students since this is a quality so badly needed at present in Canada;

Or more strongly -- that Ph.D. programs develop entrepreneurship in students. Consulting through research institutes or the like should involve Ph.D. students more than at present. This has been the practice at Windsor.

Recommendation 8. That, since there is never a valid reason for producing a second- or third- rate Ph.D., no student be admitted into the graduate training program, either at the Master's or the Ph.D. level, unless that student has obtained in undergraduate training, the equivalent of at least a B level;

This is indisputable in intent but a B level is not a guarantee of a first rate graduate degree. And, pursuit of the entrepreneurship goal may require broader entrance criteria than grades.

Recommendation 9. That there be established a Post-Entrance Acceptance Committee (PEACE) composed of representatives from all the chemical engineering departments engaged in Ph.D. education;

That this committee meet within a period of less than one month after the academic year has commenced, and that all acceptances be reviewed post facto, all available data being presented to this committee;

That, should it be found that students have been accepted who, in the opinion of this committee do not fulfill the minimum requirements, the committee advise the Council of Ontario Universities that a recommendation be made to the requisite authority suggesting no Basic Income Units be awarded for that student;

The University of Windsor would not accept the establishment of PEACE, or of any external screening committee of this kind. However, we are not averse to an annual engineering-wide disclosure of our admissions to be reviewed by CODE. This external policing would be quite adequate to guarantee general adherence to the standards of admission already laid down by Ontario graduate schools.

Recommendation 10. That,either in the financing of Ph.D. programs or by other means, the Government of Ontario take steps to strongly encourage mobility among the graduates of the universities of the Province so that a fair portion of them take higher degrees at universities other than at the one which awarded them their bachelor's degree;

We agree. Such a policy may break the present stalemate. But a wider view including all Canada, the United States and beyond may also be encouraged.

Recommendation 11. That efforts be continued in the departments to group research activities in well-defined areas so as to establish or reinforce teams, thus providing a more stimulating environment for the students;

We heartily agree. Also encourage groupings which transcend departmental boundaries where this is beneficial to the students and to the faculty.

Recommendation 12. That Ph.D. programs be the responsibility of only those staff members who have a proven or potential satisfactory research productivity and capability of supervising students;

That consequently, universities adopt and publish policies which confirm the provision of equally valid career opportunities in other areas of university activities such as teaching,student guidance and administrative duties, for those professors who have no special inclinations to participate in Ph.D. programs;

This is a crucial recommendation. Both parts of the recommendation indicate that research, if done, is to be well done. The recognition of student supervision abilities is noteworthy and long overdue. The second part may be inconsistent with recommendation 3 unless it is reworded to state -- that the undergraduate program and the graduate program be regarded as integral parts of the total educational process; one cannot exist without the other.

Recommendation 13. That the case of a department which during the next five years has not maintained an average ambient population of at least ten Ph.D. students of the caliber specified in recommendation 8, be reexamined by the appropriate authorities with a view to the temporary suppression of the Ph.D. program;

We cannot agree. The intent is critical interaction, the solution given here is critical size. Unless the desired critical interaction is measured directly in both large and small schools it should not be presumed to exist.

The recommendations which follow are pertinent to particular schools. Only recommendation 17 mentions the University of Windsor:

Recommendation 17. That the case of the Department at the University of Windsor be given particular attention by ACAP in the light of recommendation 2 and 3 and in consideration of the present excessive number of departments of chemical engineering in Ontario;

That this case be investigated in greater depth than the present study has allowed;

That in the event of any action taken with regard to the present recommendation and recommendation 3, very special consideration be given to all aspects of the relocation of staff members who in the opinion of the consultants, are the responsibility of the Ontario university system.

There are several points to be considered under this recommendation. The first of these is "the present excessive number of departments of chemical engineering in Ontario" or as stated in the conclusions of the report "there is some evidence that the number of departments of chemical engineering in Ontario is greater than called for by present needs".

The criterion for stating that the number of departments exceeds needs is a relatively high ratio of number of departments/ million population, for Ontario. This kind of ratio is fundamentally meaningless, unless applied uniformly for all learning disciplines. Perhaps it could be that Ontario has done so well because of this high ratio? Then, why go backwards?

Granting for the moment that there are too many departments of chemical engineering, the question arises as to which of these departments are 'superfluous' to the system. Although the criterion used by the consultants is not explicitly stated it is apparent to us that the consultants have applied the criterion of "critical size" in singling out both Windsor and Queen's for special consideration. This interpretation is borne out by Recommendation 13 where at least 10 Ph.D. students are required for a critical size. Further, in referring to the Engineering Process Design Division in which the entire chemical engineering department at Windsor is placed, we find "Even though the total number of faculty members in a division (20) is still small, yet the arrangement should produce good interaction between disciplines, and is really the only way in which anything approaching <u>critical size</u> can be produced". Presumably any department of less than 20 faculty is of less than critical size (In fact, only two departments in Ontario have more than twenty faculty members).

The criterion of critical size is questionable, and so are the arbitrary levels assigned to this criterion. We submit that the division structure at Windsor, in setting out to achieve critical interaction has already satisfied the objectives sought by

the critical size concept. The division structure is now in its second year of operation. A brief description of the Engineering Process Design Division, appropriate to Chemical Engineering, is attached.

Another point of interest is Table 6.1.2 which places Windsor at the bottom of a grants/ faculty member scale. The data are acknowledged to be incomplete and as such are erroneous. Hopefully such a table was not used in selecting Windsor (or Queen's) for special consideration. In any case data of such importance should be based on periods of at least 3 years, the normal residence time of a Ph.D. student. Correct data are attached.

Engineering Process Design Division

This division brings together in a formal fashion faculty and students working in research areas relating to the theory and practice of process design. The division thus encompasses personnel with research interests in thermodynamics, kinetics and transport processes. In terms of engineering practice, these fundamentals cover a wide range of applications. The membership of the division, comprising faculty members from departments of Chemical, Civil, Engineering Materials, Geological and Mechanical Engineering, reflects this diversity.

The division provides cohesion of research efforts in two ways; first, by integration of course offerings and second, by promoting interdisciplinary contact. The courses offered by the division are divided into core courses, considered important enough to be mandatory for all students within the division, and non-core courses in three special areas, namely hydrological, environmental and thermofluid. Organization of course offerings in this fashion streamlines a students' program of study, and provides him with useful exposure to the broader implications of process design principles. Furthermore, in addition to a consolidation of course offerings, the division provides a forum for mutual interaction and complementation of research expertise as well as facilities.

The major research areas represented by the membership of the engineering process design division are (i) environmental (air, water, solid and noise pollution) (ii) fluid mechanics, hydrology and hydraulics (iii) heat transfer (iv) engineering materials.

UNIVERSITY OF WINDSOR

CHEMICAL ENGINEERING

~~Corporation~~ Current Data to be Applied to Pg Table 6.1.2.

Grants-in Aid of Research (1972-73)

Dr. M. Adelman	$7,000.00	N.R.C.	$7,000.00
Dr. G. P. Mathur	5,000.00	N.R.C.	5,000.00
	2,000.00	Aluminum Company of Canada	2,000.00
Dr. A. W. Gnyp with Dr. C. C. St. Pierre and S. J. W. Price	16,455.00	Air Management Branch chrough the I.R.I.	16,455.00
	3,000.00	Hiram Walkers Limited through the I.R.I.	3,000.00
	4,000.00	Chrysler Canada Limited through the I.R.I.	4,000.00
Dr. C. C. St. Pierre	4,000.00	N.R.C.	4,000.00
Dr. R. A. Stager	4,300.00	N.R.C.	4,300.00
			$45,755.00

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A P P E N D I X D

PROCEDURE OF PLANNING STUDY AND TERMS OF REFERENCE

Procedure for Chemical Engineering Doctoral Planning Assessment conducted by ACAP in co-operation with CODE 1972-73

A. Tasks Requested from Discipline Group (with help available from ACAP at all stages)

A.1. Meet with representatives of ACAP and CODE and discuss the specialty fields assigned to this assessment. An initial meeting of the five engineering discipline groups may prove desirable. The field allocations may be altered by ACAP as a result of these discussions and CODE comment.

A.2. Suggest a panel of suitable consultants from which ACAP may choose. ACAP will refer the list to CODE for comment before acting.

A.3. Examine and comment on pro formae to be used for the gathering of information on current, past and future programmes as described in paragraph B.1.

A.4. Examine and comment to ACAP on the adequacy of the data collected on current and past strength. CODE will also be asked to comment on the data reliability.

A.5. Both in consultation with ACAP/CODE representatives and separately, consider the situation revealed by the tabulation of proposed future programmes and consider whether future plans should be modified or developed in more detail. As a result of this step, individual universities may wish to revise the material described in B.1.d below.

A.6. Possibly develop a tentative plan for development of established or new doctoral work in Ontario paying attention to adequate coverage of fields and specialties. Any such plans will be reported to ACAP which will transmit them to the consultants and to CODE.

A.7. For this assessment, the discipline group shall consist of a member of each of the Departments of Chemical Engineering, that member being the chairman unless the chairman delegates this responsibility to a colleague on a permanent basis.

B. Information from Universities

B.1. Each university is asked to supply to ACAP, in the form indicated by ACAP after comment by CODE and by the discipline group (paragraph A.3.).

information as follows:

a) for each specialty field determined in A.1.

(i) current list of faculty members showing fraction of research and graduate instruction time devoted to the field (for part-time professors show the time spent on university duties);

(ii) numbers of full-time and part-time faculty members for each of the past five years;

(iii) for the current year and preceding five years, number of (1) master's and (2) Ph.D. candidates and (3) post-doctoral fellows doing research in the field full and part-time shown separately.

Under these three headings one individual may appear under more than one category.

b) for each "department" which offers doctoral work in the fields of this assessment

(i) Curricula Vitarum of each faculty member (Assistant Professors and higher) showing inter alia complete publication lists, research funding in the past five years, and graduate students and post-doctoral fellows supervised during his career, and specialization.

(ii) resources of space - a statement indicating the department's view of the adequacy of its space, and, in connection with the future plans in (d) below, discussing future space provision;

(iii) number of Bachelors' graduates in chemical engineering and number of qualifying or make-up students each year for the last five years;

(iv) other general items relevant to research and graduate study,
a) major laboratories and equipment, over $5,000
b) computing facilities;

(v) support from related departments including shared teaching and research;

(vi) description of any inter-university arrangements for graduate work.

c) table of characteristics of graduate students in the department in previous five years, separately for Master's and Ph.D., breaking down numbers by:

(i) Full-time and Part-time;

(ii) immigration status (3 years) and country of first degree;

(iii) sources of financial support;

(iv) time to reach degree;

(v) drop-out number;

(vi) degrees granted;

(vii) post graduate employment of Ph.D.'s
a) immediate and
b) after two years.

d) proposed plans for the future of doctoral work, in as much detail as the department can provide, including the proposed scheme for support of these plans, and accompanied by supporting arguments, including consideration of the sources of doctoral students and an analysis of demand for graudates from the programmes as indicated by previous placement experience. The various headings in a) and b) above should be dealt with quantitatively where possible; as a minimum, planned numbers of faculty and doctoral students should be given. If part-time doctoral work is contemplated, please discuss in detail.

B.2. The material so supplied will be collated by ACAP and transmitted to the discipline group for action indicated in paragraphs A.4., A.5 and A.6.

B.3. Apart from the material described in B.1.d. and to some extent generated at the department level, each interested university will be requested to make an individual statement on its plans for the development of doctoral work in these fields of engineering, in particular the items of future commitment implied by item B.1.d.

Terms of Reference of Consultants

C.1. Consider the two special documents related to the coordination of the assessments in Engineering, viz. Engineering Ph.D. Planning and Assessment Procedures, Statement on Ph.D. Studies in Engineering Studies in Ontario, and the material prepared by the discipline group and the universities and obtain other data they may require to carry out the tasks detailed below. They shall be provided with copies of "Ring of Iron", the COU statement thereon, and the CODE, OCGS and APEO responses. They may obtain data and views from any relevant source, such as, for example, employers of holders of graduate degrees, professional and learned societies, federal agencies. The campus of each interested university shall be visited by at least two consultants. Consultants shall arrange their schedule of visits to the universities in consultation with ACAP to ensure uniformity. Reports of appraisal consultants are privileged documents and are not to be made available to ACAP consultants. Consultants shall meet with the discipline group near the beginning of the work, during the work as they consider necessary, and immediately before preparing their final report.

C.2. Report on the adequacy of the present state of doctoral work in "chemical engineering" in the province in general and in each university where applicable, discussing the following:

a. coverage of fields and specialties, and extent of activity in each

b. faculty quality and quantity

c. nature of programmes offered

d. enrolment size and distribution amongst universities and divisions

e. quality of student body; admission requirements

f. relationship to related disciplines and to the profession

g. physical facilities

h. other matters considered by the consultants to be significant.

C.3. Make recommendations for the development of doctoral work in fields of this assessment in Ontario between 1973 and 1978, taking into consideration such plans as may be developed by the Discipline Group, and, without limiting the generality of the foregoing, dealing with the following points:

a. Desirable doctoral programmes to be offered in the province, considering both possible limitations or reductions of existing programmes and creation of new programmes and new kinds of programmes including the appropriateness of part-time programmes. In particular, consider if there should or should not be more activity in fields now producing few graduates in Ontario and also the desirability of developing further application-oriented and inter-disciplinary work and industrial involvement.

b. Desirable provincial enrolments, year by year, in the doctoral study in chemical engineering and in the major subject divisions where appropriate. One should consider the need for highly trained manpower and also the general cultural and societal factors which may lead students to pursue doctoral work in engineering. In considering manpower needs, one should take account of the "market" available to graduates (at least all of Canada) and of other sources of supply <u>for that market</u>. Results of forecasts of high level manpower employment should be treated with due caution and only in a clearly balanced relationship with cultural and societal needs.

c. Distribution amongst the universities of responsibility for programmes and for specialties where appropriate, including consideration of the need for any increase or decrease in the number of departments offering doctoral work and including consideration of areas of collaboration and sharing of facilities at regional level and across the province. Consider techniques for involvement in doctoral supervision of professors in departments which do not take doctoral students in their fields, and the extent to which such activity is desirable.

d. Distribution of enrolment amongst the universities, showing desirable <u>ranges</u> of enrolment.

In all cases, it is important that the rationale for the recommendations be clear; this is especially important for items c. and d.

C.4. It is permissible for consultants to recommend appraisals of individual programmes. This would arise if consultants were to suspect that a programme would be found to be wholly or in part below minimum acceptable standards; and appraisal by the Appraisals Committee is the means of settling the question. It is recognized that this action would be infrequent. In carrying out planning assessments in some disciplines, consultants find there to be an excess or deficiency of programmes in a given area of study, where all of the existing programmes could pass an appraisal, they may, subject to their own judgments of relative

quality and of other factors (a task outside the terms of reference of the Appraisals Committee), recommend where enrolment should be changed in accordance with the possibilities indicated in section C3 (c).

D. Appointment of Consultants

The consultants shall include one person of wide academic experience in Canada but in a different discipline. The other two consultants shall be engineers of international standing, with suitable administrative and/or teaching experience, and with expertise in some of the fields assigned to the chemical engineering assessment.

E. Report of Consultants

The consultants submit a joint report to ACAP (tentative date of September 1973). Minority reports are, of course, possible. The reasoning leading to their recommendations should be given fully, in view of the subsequent treatment of the report. The report is submitted for comment to CODE, to the discipline group and to each interested university. There may be informal or interim exchanges of views amongst the discipline group, the universities, CODE and ACAP. Any university which wishes to make a formal statement to COU on the consultants' report shall submit it to ACAP. Any such report shall be transmitted to CODE and to the discipline group. The discipline group shall submit its formal comments and/or recommendations to ACAP and CODE. CODE submits to ACAP its recommendations to COU. ACAP considers the CODE, discipline group and university statements along with the consultants' report and transmits them to COU with its recommendations of the position COU should adopt. Copies of the material transmitted to COU will be supplied to CODE, to OCGS, to the members of the discipline group and to the interested universities. CODE, OCGS and the universities are thus enabled to prepare for direct comment to a COU meeting. The consultants' report may be published together with the comments of CODE, the discipline group and those of any university so requesting, and with the position adopted by COU.

Amended November 29, 1972.

Engineering Ph.D. Planning and Assessment Procedures

Coordinating Task Force, September 25, 1972

1. The doctoral assessments in Engineering are being conducted as a group. To that end there has been established a Coordinating Task Force to coordinate the conduct of the assessments in accordance with the procedures outlined in this document which is referred to in section C1 of the Terms of Reference for the Consultants.

2. All "departments" of each Engineering Faculty shall prepare a statement presenting their current and proposed Ph.D. activities including:

   (a) areas of research and study
   (b) educational goals and style
   (c) enrolment ranges projected to five years, and other items as defined in section B of the approved "Procedure", including the basic ACAP quantitative data sheets as modified for the engineering assessments.

   The quantitative data sheets, to be submitted to ACAP by November 1, 1972, and the "five-year plans", due by the end of January 1973, will then be distributed by ACAP to the discipline groups for consideration and planning action by the individual institutions and by the discipline groups. Copies will be made available to the members of CODE.

   Departments are encouraged to discuss their preliminary plans with the appropriate discipline group prior to formal submission in January and the discipline groups should be active in their planning function throughout this period.

3. Each Discipline Group will be charged to prepare from the statements a report on Ph.D. activities and plans in their discipline area, noting both apparent conflicts and gaps in both areas of specialization and enrolments. Reports will be distributed as above, by the end of February 1973.

4. Each University may modify the above statements in the light of the above and in consultation with the Discipline Groups and other Universities as appropriate. Subsequently the Discipline Groups will finalize their reports, which are due to ACAP by April 15, 1973.

5. These statements and reports, along with the regular ACAP assessment data (to be prepared during the above process, perhaps with CODE "data bank" collaboration) shall form the data base for the assessment teams. Failure to meet deadlines will not be allowed to delay proceedings.

5. The Coordinating Task Force will review the detailed terms of reference to be given to the consultant teams, particularly in the educational professional areas. This is scheduled for completion by September 30, 1972.

6. Upon completion of (4) above, the Coordinating Task Force shall recommend to CODE and ACAP whether areas in Engineering not clearly included within the five major discipline areas shall be included within the total of engineering activity without further review, or included within one or more of the major discipline studies, or be subject to a small special assessment process.

7. CODE, with assistance from COU and utilizing outside expertise as needed, shall implement a special study of the engineering manpower situation at the Ph.D. level. This study should be available for consideration by ACAP, the Discipline Groups and the consultants prior to the drafting of final reports and responses. Reports on the progress of this study shall be reviewed by the Coordinating Task Force; the first report shall be due by the end of 1972.

8. The formal assessment and consultative process shall commence on completion of (4) and the consultants shall be provided with a general statement, in addition to the data base material, terms of reference, and other relevant documents. This statement which has been prepared by the Coordinating Task Force and is referred to in section C1 of the Terms of Reference for the consultants is intended to draw attention to some features of the Ph.D. in Engineering which the Task Force considers distinctive enough to merit particular consideration by the consultants. Educational, professional and research concerns will be emphasized. Briefings and discussions with ACAP and the appropriate Discipline Group will complete the first stage of this process. These discussions are expected to occur about one month prior to the first visits and the visits themselves will be concentrated in the month of May and June.

9. The next stage consists of consideration of the available material by the consultants, University visits, meetings with the Discipline Group, and the preparation of a draft report by September 1, 1973.

10. The draft reports will be made available to the Engineering Deans and to the Discipline Groups to provide for initial feedback to the consultants. There will be oral response from the Discipline Groups to the consultants. Following this the consultants will draft their final reports which will be followed by official responses from the above groups and finally by consideration by COU. (The above is intended to make clear that while feedback to the consultants from the Discipline Groups is desired and expected, the draft reports are not to be distributed for open discussions within departments.)

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APPENDIX E

DISCIPLINE GROUP MEMBERSHIP

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APPENDIX E

DISCIPLINE GROUP MEMBERSHIP

McMASTER -	C.M. Crowe
OTTAWA -	B.C.Y. Lu
QUEEN'S -	J. Downie
TORONTO -	W.F. Graydon
WATERLOO -	K.F. O'Driscoll
WESTERN -	H.A. Bergougnou
WINDSOR -	M. Adelman

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APPENDIX F

ROLES OF ACAP AND OF DISCIPLINE GROUPS

Ontario Council on Graduate Studies

By-Law No. 3

A By-Law to establish a Committee on the Academic Planning of Graduate Studies.

1. The Ontario Council on Graduate Studies, recognizing the importance of providing for the continued and orderly development of graduate studies in the Ontario universities, establishes a Standing Committee to be known as the Advisory Committee on Academic Planning (abbreviation - ACAP).

Interpretation

2. In this By-Law

   (a) "Committee" without further specification, means the Advisory Committee on Academic Planning;

   (b) "Council" or OCGS means the Ontario Council on Graduate Studies;

   (c) "Committee of Presidents" or CPUO means the Committee of Presidents of Universities of Ontario;

   (d) "university" means a provincially assisted university in Ontario;

   (e) "discipline" means any branch or combination of branches of learning so designated;

   (f) "discipline group" means a body designated as such by the Committee of Presidents of the Universities of Ontario, and normally consisting, for any one discipline, of one representative from each of the interested universities;

   (g) "planning assessment" means a formal review of current and projected graduate programmes within a discipline or a group of disciplines;

   (h) "programme" signifies all aspects of a particular graduate undertaking;

   (i) "rationalization" means the arranging of graduate programmes in order to avoid undesirable duplication, eliminate waste, and enhance and sustain quality.

Membership

3. (a) The Committee shall consist of at least seven members of the professoriate in Ontario universities, some of whom shall be members of the Council.

(b) The members of the Committee shall serve for such periods of time as the Council may determine, and they shall be selected in such manner as may provide for reasonable balance both of academic disciplines and of universities.

(c) The members of the Committee shall be appointed as individuals.

Chairman

4. The Chairman of the Committee shall be named by the Council, and he shall have one vote.

Quorum

5. A majority of all members of the Committee shall constitute a quorum.

Functions

6. The functions of the committee shall be

(a) To advise OCGS on steps to be taken to implement effective provincial planning of graduate development;

(b) To promote the rationalization of graduate studies within the universities, in cooperation with the discipline groups;

(c) To recommend, through OCGS, to CPUO the carrying out of planning assessments of disciplines or groups of disciplines and to recommend suitable arrangements and procedures for each assessment;

(d) To supervise the conduct of each planning assessment approved by CPUO;

(e) To respond to requests by CPUO to have a discipline assessment conducted by proposing suitable arrangements;

(f) To submit to CPUO the reports of the assessments together with any recommendations which the committee wishes to make. A copy of the report shall be sent to Council.

Jurisdiction

7. In order that the Committee may discharge the functions described in Section 6 above, it shall be authorized

(a) to request a university to provide such information pertaining to graduate studies as may enable the Committee to discharge its functions;

(b) to request a discipline group to provide such information as may enable the Committee to discharge its functions;

(c) to receive reports from the universities and from the discipline groups, and to comment and communicate with the universities and the discipline groups concerning such reports;

(d) to convene a meeting of any discipline group for the purpose of discussing the development to date, and proposals for the future development of graduate studies in the discipline concerned;

(e) to send one or more representatives to a meeting of a discipline group at the invitation of the discipline group;

(f) to make such suggestions to a discipline group as may be deemed appropriate to the functions of the Committee;

(g) to supervise the conduct of planning assessments, and to report thereon to the Committee of Presidents of Universities of Ontario;

(h) generally to report and to make recommendations to the Council;

(i) to seek and receive advice from appropriate experts;

(j) to employ consultants in connection with planning assessments.

Procedures

8. The procedure to be followed by the Committee shall be as approved by the Committee of Presidents of the University of Ontario.

9. The Committee's function is solely advisory.

Effective Date

10. This By-Law shall take effect January 1971.

ACAP DISCIPLINE GROUPS AND THEIR ROLES

1. Establishment of a Group

a. When it is considered desirable to activate planning of graduate work in some discipline(s) or interdisciplinary area, COU, on the advice of OCGS, will authorize the establishment of an ACAP discipline group, if it was not already approved and included in the May, 1968 list. If it is already authorized, ACAP may decide to set it up as described in paragraph b.

b. The Executive Vice-Chairman of ACAP will then invite the executive head of each university (including Waterloo Lutheran University) either to nominate a member of the discipline group or to indicate that his university has no plans for graduate study in this discipline in the next five years or so. If a university can state no plans for future graduate work in the subject, but feels that a watching brief is desirable, it may appoint an observer to the group.

c. Changes of a university's representative are to be notified by the executive head.

d. The group shall select its own chairman.

2. Meetings

a. A discipline group may meet at the call of its chairman or in accord with its own arrangements.

b. A discipline group may be called to meet by the Executive Vice-Chairman acting for ACAP.

3. Responsibilities

a. The group is to keep under review the plans for graduate work in its discipline in Ontario, including new developments and trends in the discipline, and to make reports to ACAP on a regular basis.

b. The group may make recommendations to ACAP in connection with graduate work in its discipline when it considers it appropriate.

c. ACAP will assist the group in obtaining information and data, as mutually agreed.

d. When COU has instructed ACAP to conduct a planning assessment, the discipline group will assist and advise ACAP in determining procedures and terms of reference, will report as requested and will generally facilitate the assessment.

Approved by OCGS March 22, 1973
and by COU April 6, 1973.

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APPENDIX G

CURRICULA VITARUM OF THE CONSULTANTS

PIERRE GRENIER

Born Quebec City, Quebec, August 15, 1922

B.A., Garnier College, 1942
B.Sc.A., Laval, 1946
M.S., Columbia, 1947

Quebec Department of Mines, Research and Development Engineer, summers 1946-51
CARDE, Valcartier (DRB), Research Associate, summers 1952-60
Laval University, 1947-
- Assistant Professor, 1947
- Associate Professor, 1950
- Professor, 1955
- Chairman of Department of Chemical Engineering, 1965-69
- Dean, Faculty of Science, 1969-

Fellow, Chemical Institute of Canada, President, 1972-73
SCITEC, Member of Council, 1972
Member, French-Canadian Association for the Advancement of Science (ACFAS)
Member of NRC Grant Selection Committee in Chemical and Metallurgical Engineering, 1968-70
- Committee Chairman, 1969 and 1970

Member, NRC Standing Committee on Grants and Scholarship, 1969-
Member, NRC, 1972-

Material and energy balances; unit operations; transport phenomena.

Address: Faculty of Science
Laval University
Quebec 10, Quebec

WILLIAM ROBERT MARSHALL, JR.

Born Calgary, Alberta, May 19, 1916

B.S., Illinois Institute of Technology, 1938
Ph.D., Wisconsin, 1941

E.I. du Pont de Nemours and Company, Engineering Department, Engineering Experiment Station, 1941-47
University of Delaware, Instructor, Extension Division, 1944-45
University of Wisconsin, Associate Professor, 1947-53
University of Wisconsin, Professor, 1953-
- Associate Dean, College of Engineering, 1953-57
- Executive Director, Engineering Experiment Station, 1953-71
- Dean, College of Engineering, 1971-

Member, National Academy of Engineering
Member, American Institute of Chemical Engineers
Member, American Institute of Chemists
Member, American Society for Engineering Education
Member, National Academy of Engineering
Member, Society for the History of Technology

American Institute of Chemical Engineers, President, 1963
Argonne National Laboratory, Chemical Engineering Review Committee, 1958-66
- Policy Advisory Board, Member, 1965-66

National Science Foundation
- Advisory Committee for the Engineering Division, 1965-67
- Chairman, 1965 and 1966

American Institute of Chemical Engineers
- Best Paper Award, 1950
- Institute Lecturer, 1952
- Walker Award, 1953
- Professional Progress Award, 1959
- Phillips Lecturer, 1973
- Founders Award, 1973

Address: Office of the Dean
258 Mechanical Engineering
University of Wisconsin
Madison, Wisconsin 53706
U.S.A.

LEO YAFFE

Born Devil's Lake, North Dakota, July 6, 1916

B.Sc., Manitoba, 1940
M.Sc., Manitoba, 1941
Ph.D., McGill, 1943

Atomic Energy of Canada Ltd., Project Leader, Nuclear Chemistry and Tracer Research, 1943-52
McGill University, Special Lecturer, 1952-54;
Associate Professor, 1954-58
Macdonald Professor of Chemistry, 1958-
Chairman, Department of Chemistry, 1965-72
International Atomic Energy Agency, Vienna, Director of Research and Laboratories, 1963-65
Visiting Professor, University of California, Berkeley, 1962

Fellow of the Royal Society of Canada
Fellow of the American Physical Society
Fellow of the Chemical Institute of Canada

Research Collaborator, Brookhaven National Laboratory, 1948-
Associate Editor, Journal of Inorganic and Nuclear Chemistry (London), 1961
Associate Editor, Radiochemical and Radioanalytical Letters (Budapest), 1969-
Member, Chemistry Grants Selection Committee, NRC, 1967-70
Member, Conseil des Universités (Québec) 1971-72

Nuclear fission; mechanism of nuclear reactions; isomer studies; absolute disintegration rate studies.

Address: Department of Chemistry,
McGill University,
P.O. Box 6070,
Montreal 101, Quebec.

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APPENDIX H

RESPONSE OF THE COMMITTEE OF ONTARIO DEANS OF ENGINEERING

COMMITTEE OF ONTARIO DEANS OF ENGINEERING

RESPONSE TO ENGINEERING PhD ASSESSMENTS

Preamble

Individual reports of PhD Assessments have already been received by discipline groups and by individual universities. Both bodies will undoubtedly make detailed commentary on the specific reports which are of direct concern or interest. In view of this, CODE has decided to forego comment on such specifics, and has determined to refer only to those matters of a more general nature which affect the universities collectively. In choosing to frame its response in unitary fashion, CODE wishes, at the outset, to emphasize that it views engineering education and practice as a total activity instead of a discrete set of unrelated disciplines such as Chemical, Civil, Electrical, Materials, Mechanical and Metallurgy, etc. This theme of relationships between disciplines within a faculty, and indeed between faculties, will recur later in the report in subsequent discussions.

Of the ten topics on which CODE sets out its 'responses', three are considered to be of primary importance - manpower, quality, and critical size. Consequently, they have been covered in somewhat greater detail than have other topics of interest, in order to provide identification and emphasis, rather than a fully developed 'position'.

The primary concern in this response is unquestionably that of quality over quantity. In assuming this position CODE realizes that the indicators of quality are undoubtedly staff, students, programmes and facilities. It is difficult to assess the precise hierarchy of these four basic parameters. Suffice it to say that, while the first two are paramount in terms of establishing potential for excellence, the last two are important in realizing this excellence.

CODE offers its resources in such further and subsequent amplification as may be useful to the purposes of the Council of Ontario Universities.

Manpower

CODE is in agreement with the general observations of the consultants with respect to the PhD manpower situation. It appears clear that the supply of PhD candidates will be limited by the availability of high quality entrants. The relatively small numbers of Canadian graduates entering PhD programmes is a cause for concern. If Canada is to advance industrially, it would be expected that there would be an increasing demand for high-technology support. An under-supply of PhD graduates in engineering would not be in the best interest of society. There is clearly no evidence of any

over-supply because of the way engineering graduates at all levels are seen to diffuse widely through industry, commerce and government; there appears no prospect of this becoming a problem in the future.

CODE realizes the importance of maintaining up-to-date knowledge of positions taken by the PhD graduates of the Ontario Engineering schools and intends to ensure that such information is updated annually. A copy of a recent survey is included as part of this response. It will be noted from this survey that there has been a shift in the area of employment of engineering PhD's towards industry.

In the light of the consultants' analyses, and of the appended data, there is no need for quotas or ceilings on doctoral students. CODE will continue to report on the number and origins of doctoral students in the various engineering schools, on an annual basis.

Quality Emphasis

(a) Admission

CODE is pleased to note that the consultants have agreed that high admission standards to engineering doctoral programmes generally prevail.

CODE, therefore, supports the contention that existing minimum entrance standards to PhD programmes should be maintained across the Province. CODE believes that a post facto analysis of admission practices, widely publicized, will be adequate to ensure this objective.

In application of these standards, it must also be acknowledged that certain defensible exceptions will occur with respect to those with known special abilities or those who have demonstrated superior ability in research, design and innovation in their post-baccalaureate experience.

CODE fully supports the view of the electrical consultants that it is "in Canada's interest, especially in international competition, to have strength in high-technology research and development" and for this to happen there must be an objective of "high standards of excellence with emphasis on quality".

(b) Programmes and Faculty Facilities

CODE recommends that totally independent and representative bodies continue to oversee negotiated development grants and the formation of centres of excellence. These are matters better left outside the jurisdiction of such a body as CODE.

(c) Undergraduate/Graduate Programme Relationship

CODE supports the contention that the continued existence of a live, up-to-date undergraduate programme requires the backing of a good

research programme and participation in professional practice by members of the faculty. The research activity, in the prevailing tradition, is most easily met through the provision of Master's and PhD postgraduate programmes.

(d) Quality Indicators

In addition to the observance of university regulations, and the use of high calibre external examiners, the observed career performance of doctoral graduates can be used as a 'quality indicator'.

Critical Size for Doctoral Programmes

In order to be viable, a PhD programme must provide a sufficient range of interaction for the student. He must be exposed to enough faculty members and enough other students to provide adequate breadth of experience and instruction. The adequacy of this breadth cannot be judged exclusively by the size of the department in which he is registered.

The ACAP assessments, by being completely vertical, miss the rich horizontal components which can and do nourish and sustain viable doctoral programmes in both small and large departments and faculties. Resources from other divisions of the university, other engineering departments, industry and, indeed, other engineering faculties must be considered in any realistic analysis of PhD programme viability.

Size is not a sufficient criterion for judging whether a school can offer a PhD programme; there is no a priori reason why a small school cannot provide as satisfactory an environment for the student as can a large school.

Engineering in the Wider Context

CODE would draw attention to the need to view the totality of the PhD programmes in engineering not just in isolation, but also in the context of other related disciplines; e.g. physical, life and social sciences.

To progress technologically in such a way as to improve the quality of life not only in Canada but also in other parts of the world, it is essential that there be work proceeding concurrently in the forefront of various other disciplines which impact on engineering. It is anticipated that increasingly advanced work in various areas will need to proceed in a more integrated fashion and it will be essential to have available high level manpower in the physical, life and social sciences, economics, and management, for instance, together with similar capabilities in engineering.

Research Emphasis and Relevance

As a result of the ACAP Engineering Assessments, there is now readily available information about research projects underway in all the Ontario

Engineering Schools. The system would have profited more had the consultants commented in detail on this information and offered substantiated specific advice on the topics of emphasis and relevance.

CODE feels that PhD programmes in engineering should be flexible enough to cover a broad range of topics. Research activities could and should range from mission-oriented research of an immediate and perceived social or industrial relevance through to very fundamental or basic research. The overall thrust of PhD research programmes should be towards advancing fundamental engineering knowledge required for the solution of present and future engineering problems.

CODE also feels that a plurality of sources of research support is a relatively effective means of ensuring that a broad spectrum of research activity is undertaken within the engineering schools. The existence of a variety of granting bodies, with a spectrum of interests represented, including a significant academic component, appears to be an effective method of control.

Level of Support for Doctoral Students

CODE strongly supports the contention that levels of support for doctoral students must be increased substantially if more Canadian students are to be attracted to entering doctoral programmes in engineering.

It should be noted that foreign graduate students have been willing to undertake PhD studies at the levels of support available and have subsequently filled positions within Canada. Positions have been available for PhD's - these have been filled largely by landed immigrants who have either completed PhD study in Canada or who have come to Canada with a PhD.

The recent increases in both the cost of living and salaries offered by industry to engineering graduates makes it even more urgent that immediate action be taken to increase the support for doctoral students. This is particularly true if post-baccalaureate experience students are to be attracted. Therefore, it is important that more opportunities be available for this particular type of doctoral student in engineering.

Part-Time/Non-Resident Work

CODE would encourage continued experimentation in this regard. It is felt that maintenance of some institutional contact is essential, however. It is felt further that any part-time or non-resident work should normally be by individual arrangement. This would not, of course, preclude special arrangements between a research institution or industry/government laboratories and a particular university or universities.

Inter-University Activities and Facilitating Mechanisms

CODE would support any action designed to increase the effectiveness of the provincial resources in faculties of engineering. The holding of discipline meetings, the sharing of equipment, interchange of credits for

graduate courses, collaboration between groups within various institutions and so on are to be encouraged. It is emphasized that co-operation often involves travel and other expenses that are not always readily available in individual schools and that this matter is worthy of further investigation.

It is noted that inter-university activity is proceeding especially at the 'grass-roots' level and this can be aided and abetted by CODE. It is also noted that various university industrial research institutes and similar agencies have facilitated some inter-university co-operation largely through use of individual expertise existing at various institutions.

The Role of the PhD in Entrepreneurship

CODE feels that entrepreneurial activity by PhD's is something which cannot be legislated. However, it feels further that the PhD has, by virtue of his total background, significantly greater potential for success in such activity than has the member of the general populace. It suggests that there are two avenues of encouragement which can lead PhD's in greater numbers into entrepreneurship. The first depends on the educational institution itself, which must, by appropriate orientation and emphasis, develop an interest in or leaning towards innovation, independent practice, or entrepreneurship. The second depends on progressive government support programmes of various kinds, directed to reaching a 'climate' competitive with that found in other industrial economies of comparable size.

Cost-Benefit of the ACAP Studies

CODE has noted that no major measures are proposed that would greatly enhance the quality of the PhD effort in Ontario. Indeed, CODE records its pleasure at the broad and independent affirmation of the consultants as to the strengths and qualities which have developed in Ontario PhD programmes.

The full programme of ACAP studies is as yet incomplete. CODE has yet to be convinced that the extensive funds and efforts devoted to the studies would not have been better spent in direct support of existing PhD programmes in engineering.

ANS/dd
December 27, 1973

APPENDIX A

REPORT ON THE CODE ENGINEERING DOCTORATE EMPLOYMENT SITUATION, OCTOBER 1973

In November 1973, members of the Committee of Deans of Engineering of the Province of Ontario again supplied data on the status of their engineering PhD graduates during the period November 1972 until October 1973. The results are compared in Table 1 with those for 1972.

Again this year, the majority of the graduates were in Chemical, Civil, Electrical and Mechanical Engineering. The total is up substantially to 177 from 124 in 1972.

Unemployment is up from one in 1972 to three in 1973 (approximately 1.7% of the total).

Approximately 17% have left Canada, which is the same as for previous years and is probably due to the return of foreign students to their home countries.

A notable increase in employment in industry has occurred, up to 33% from 21% in 1972. The number employed in Canadian universities is up to 26% from 21% in 1972. This has been accompanied by a decrease in post-doctoral fellowships from 23% to 11%.

The overall conclusion is that there is still no serious unemployment among recent Ontario PhD graduates in Engineering despite predictions to the contrary. In fact, a healthy trend toward their increased utilization in Canadian Industry may have been established.

December 13, 1973.

ONTARIO ENGINEERING PH.D EMPLOYMENT SURVEY 1973

The employment status of one hundred and ninety-two graduates with PhDs in engineering from Ontario universities during the period November 72 to October 73 was determined in November 1973.

ENGINEERING DEPARTMENT OR DISCIPLINE	Unemployed		No professional Employment		Employed in Industry		Employed in Government		Employed in Universities		Postdoctoral Fellowships		Have left Canada		Unknown		TOTALS	
	1972	1973	72	73	72	73	72	73	72	73	72	73	72	73	72	73	72	73
Aero/Space	-	-	-	-	1	3	-	-	1	3	4	1	-	-	-	-	6	7
Bio-Medical	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
Chemical	-	1	-	-	4	13	1	3	7	5	7	5	3	2	4	2	26	31
Civil	-	1	-	-	5	7	2	5	3	14	6	5	9	7	5	-	30	39
Electrical	-	-	2	-	9	20	3	2	5	11	7	5	4	9	1	-	31	47
Industrial	-	-	-	-	2	-	1	-	2	-	-	-	-	-	-	-	5	0
Materials/Metals	-	1	-	-	1	6	1	-	1	3	2	2	-	3	-	-	5	15
Management	-	-	-	1	-	-	-	-	1	1	-	-	-	1	-	-	1	3
Mechanical	1	-	-	-	4	9	2	5	6	8	1	1	2	7	2	1	18	31
Mining	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
Physics/Science	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	2	0
Systems Design	-	-	-	-	-	-	-	1	-	1	-	-	-	2	-	1	0	4
TOTALS	1	3	2	1	26	58	10	16	26	46	28	19	19	31	12	4	124	177

APPENDIX B

Comments on CEMC Report

"Supply and Demand for Engineering Doctorates in Canada" (July 1973)

Submitted by the Committee of Ontario Deans of Engineering

Commendation of this report can be made in a general sense on two main scores. Firstly, the consultants have, on assignment, tackled in a straightforward manner, what is generally acknowledged to be a most difficult task indeed; where qualitatively it is not possible to assert all possible parameters, and quantitatively, it is not possible to obtain reliable data on all accepted parameters.

Secondly, the consultants have in their report introduced with some care statements relating to the qualifications and limitations of the many elements entering into their predictions, and have emphasized that this is only a beginning - ergo, a very preliminary report.

Within this general context, however, there are a number of criticisms to be advanced.

1. Supply

The methodology has been clearly enunciated, and the assumptions stated. Nonetheless, projections have been made on a three-level approach (high, medium and low), establishing bounds which may well be broken as and when certain assumptions become less or more operative. Some indicators are already present as to the dangers of some of the assumptions.

1.1 Admission requirements are not static, and are increasingly adaptable to the changes in the high school. Three other important aspects must be added. There is, firstly, foundation for expecting a major growth in the number of women entering engineering. Secondly, the "market-place" reaction with a rapid response in the 1st year enrolment to a proclaimed shortage in engineers will continue to be operative. Thirdly, there is further indication that advanced admissions (through the stop-outs returning, through technology graduates admissions, etc.) are increasingly important in enrolment projections. None of these has been clearly taken into account in this report. A further aspect could well be added, which is also ignored in the report, but is less easy to define though it will contribute to the instability in prediction of 1st year enrolment. This relates to measuring the full impact of major educational changes on the Canadian scene. The effect of the CEGEP's in Quebec in particular, as well as of the CAAT's in Ontario, is yet to be clearly perceived, let alone settled into a measurable or stable influence.

1.2 The two data bases selected for examination were the number of master's degrees and the number of baccalaureates. The discarding of the master's degrees/doctorate degrees ratio as credible seems to ignore the very recent development of many doctorate programmes as contributing to a rapid change in this ratio. The total postgraduate effort in engineering in Canada is of such an emerging character that rates of change must be evaluated much more carefully. This is equally true for the baccalaureate/doctoral ratio selected as a data base. The evidence for stabilization in this is slight, and even the selection of three ratio levels is likely subject to major error through neglect of variable factors in an easily perturbed system. The changing pattern in the number of Canadian baccalaureates who earn doctorates outside the country is one further feature of a system which as yet has little maturity or stability in it. This aspect of immigration was noted in the resport as one for which no data was available - which ignores one fully-documented part of the system, the Athlone Fellows.

1.3 The utilization of the baccalaureate/doctoral ratio as a data base for predicting future supply has another feature which is inadequately considered and analysed. This relates to the forces which are operative on graduates of Canadian engineering schools vis-a-vis their proceeding to doctoral work. Graduates of the engineering schools of Canadian universities have never come forward in substantial numbers to undertake advanced study and research. The tradition of such a choice, and indeed the number of opportunities for such advanced work, are relatively new on the Canadian scene. The expansion of the graduate schools over the past decade has been effected therefore by the attracting of students with overseas degrees, particularly from Asia. Many of these students from overseas have been or have become landed immigrants, have stayed in Canada and have taken jobs as PhD's. These jobs have been available, they have not been taken up by Canadians who seem to have preferred to enter the work-force earlier, immediately after obtaining the bachelor degree. There are probably many factors which have conditioned the particular choices of Canadian engineering graduates at the bachelor level, but primarily it is probably a combination of (a) the fact that they have been so readily absorbed into the economy at that level, and (b) the fact that the level of financial support available for graduate study has been too low to make them feel that the sacrifice is worth it. For the near future, unless the proportion of Canadian bachelor degree graduates choosing to undertake PhD studies changes drastically, the numbers of qualified applicants coming forward will certainly decline. At the same time as the graduate schools in engineering become increasingly well established and recognized, and as high technology factors including its encouragement through government policies increasingly become operative, the opposite effect could well occur. The imprecision therefore in assuming a stabilized bachelor/doctoral ratio is greater than assumed in the CEMC study.

1.4 In the consideration of the report, moreover, one should not perhaps overlook the possible impact of events occurring in other jurisdictions. The report suggests that the annual number of bachelor degree graduates will fall from about 4,500 to 3,000 over the next three years, with most of this decrease due to a falling-off in freshmen enrolments in provinces other than Ontario. This could suggest in itself a likelihood of fewer qualified Canadian graduates available for PhD studies at our universities. This must be viewed in conjunction with the situation in the U.S. where undergraduate enrolments in engineering have fallen very sharply over the last few years and this will lead to a very substantial decrease in the number of bachelor engineering degree graduates over the next few years. The combined Canada/U.S. graduating class was about 47,000 in 1971. It will be only about 35,000 in 1975. One might wonder whether, because of excellent opportunities at the bachelor level, a smaller proportion might proceed to PhD work or conversely whether the lack of anxiety about employment prospects at the bachelor level will give more students the confidence to continue with their studies.

1.5 A further major criticism of this part of the report rests not on the methodology, elements of which have been discussed above, but on the basic data used in the calculation steps. Without examination of each and every set of data used, it can nonetheless be indicated that the rather complex combinations of undergraduate enrolment and graduation data from Statistics Canada, from EIC enumerations, from the "Ring of Iron" for Ontario leave some inconsistencies. The number of bachelor's graduations and of doctorates were obtained only to 1970-71, while the number of master's degrees were recorded for 1971-72. In view of the rapid build-up in Canada of doctorate degrees (from 78 in 1965-66 to 216 in 1970-71) it would have seemed to be quite important to establish the 1971-72 figures before final projections were carried out. In view of the prominent place taken by the Ontario system contribution it is indeed surprising that more current data at hand in COU (ACAP) was not utilized. Nonetheless, it is fair to point out that the actual doctorates in Ontario for 1972 and 1973 respectively were 124 and 177, and that the former figure compares to the low level projection for 1971-72 of 126, and the latter to the high level projection of 172 for 1972-73. At least the projection band width used just encompasses the first stages of comparative actual data.

2. Demand

The report includes a comprehensive survey of manpower demand methods, and a careful statement of the method followed for each of the sectors explored, as well as its limitations. This demand aspect of the report is the one which has received the most criticism from the ACAP consultants in the five engineering fields assessed. Our criticisms encompass the major elements of those comments in summary form as well as those voiced by the engineering schools in Ontario.

2.1 Educational Sector

The consultants' use of a model for the estimation of future demand in the educational sector is deceptively attractive. Essentially, their model was based on a staff-student ratio as a base, adjusted for retirement, mortality and migration. They concluded that to 1977-78 (at least) the demand for engineering doctorates would be essentially zero, and then admitted "this will not prove to be an accurate scenario". They then rest their case that in both universities and other educational institutions, the demand will be "minimal". In the dictionary sense of the least attainable or extremely minute in size, it is difficult to read into this other than essentially no demand. Even though rather elegantly derived, we find it hard to accept such a conclusion, particularly when the Ontario system itself projects now a demand for about 20 for 1974. Some of the parameters which would be omitted by the model used include increased demand through major block research grants, through mission-oriented research, and through the development of new programmes and areas. The report does deal at length with the question of "substitutability between inputs", but does not weigh it to the level where it would not be balanced by other factors. This question of substitution will also be referred to below in considering the total demand-supply picture.

2.2 Government and Industry Sectors

In these sectors the consultants chose to establish stock data and forecast demand for 1974, 1975 and 1978 by direct survey. From the many criticisms and indeed specific refutations that can be made, it is clear that this survey has been far too narrowly cast. In the government area this is certainly true regarding the narrowness of definition used. In the industry area it includes not only that limiting factor, but became subject to both incomplete data through using wrong sources, and through important omissions. To some degree the consultants were well aware of these deficiencies, but were obviously more conscious of them for the forecast demand data than for the stock data - where equally gross errors and omissions seem to have occurred. One example of such an error is in the stock of 52 in 1973 attributed to AECL, compared to the 90 actual in 1973 as provided by the Metallurgical engineering consultants in their report to ACAP. Other reports to ACAP specify other examples.

It is hard to escape the conclusion that the inadequacies of the demand survey are far greater than the consultants envisioned, and their errors of omission are much greater than they estimated.

3. General

3.1 Educational Planning and Manpower

What appears to be a basic premise of the report as contained in paragraph 1 on page (1) deserves comment, viz.,

"Now, a generally accepted view is that the expected labour market for graduates of a particular speciality should influence policy and planning in post-secondary education in that area."

This view may not be as generally accepted as one might be led to believe. The particular philosophy outlined can, taken to extremes, result in a shortsighted and constrained view of a university. It could well be argued that too marked a distinction has been drawn between what is educational and what is vocational. Recently this has been convincingly stated to be one of the major misconceptions in higher education planning*. The danger in assuming that all but preparation of people for specific jobs is wrong or wasteful is not just in the short-sighted effort to establish a one-to-one relationship between education and jobs. Rather it omits the important fact that vocationally oriented education is not wasted if it is not used in the specific vocation toward which it was directed. As Bowen* states, "It is no mark of failure, rather a mark of success, that education - even strictly vocational education - has wide applicability and produces flexible and versatile people". The PhD graduate even if he takes a vocational route initially may well very soon find himself in positions where his PhD can be regarded only as part of his general education or as a contributing factor to his intellectual development or problem-solving ability. It is not difficult to give examples of this "diffusion" of PhD's through a "vocational" period to positions of quite different responsibilities in industry, governments and the universities. The consultants gave careful attention at one stage in their report to this "diffusion" or dispersion, referring properly to the recent University of Toronto study. However, they did not then "factor" it in to either their supply or their demand projections. In our view, significant allowance should be made for it. On the supply side, both into the baccalaureate stream as well as into the doctoral stream in engineering the vocational/educational issue is not clear-cut nor should it be. On the demand side, there must be allowance made both for the substitutability through flexibility even at initial employment levels, and for increasing mobility and transfer into wider areas such as management as experience accrues. The difficulty of quantifying this is well appreciated. The need for including it in some definitive way demands equal appreciation.

3.2 The Supply and Demand Balance

The report in its final results and conclusions comes down strongly on the prediction of an oversupply of engineering PhD's in the decade ahead. They acknowledge a range of factors which will influence both their supply band projection and their demand band projection, including the possible effect of their own report. We acknowledge this danger and can only hope that it can be minimized by vigorous emphasis both

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* H. R. Bowen, "The manpower vs. the free-choice principle", University Affairs, Jan. 1974.

on the limitations of the report's projections but also on the countering evidence as it accumulates. We have indicated some of the aspects of both the supply and the demand projections which can invalidate the narrowness of the band widths selected. Perhaps more importantly in the long run is the real failure of any demand projection to be able to take into account any but the very short-term skill requirements of the economy. The evidence is quite clear that our society has an enormous amount of work to be done with a lack of sufficient skilled manpower to do it. We would claim that the adaptability of doctoral graduates in general combined with the adaptability of our economy results in a surprisingly good balance. The Ontario experience, well documented now for four years, indicates essentially no unemployment of engineering doctorates, no unusual hold-up or storage in a post-doctoral form, and changing flows into government and industry as demand from the universities slacken. The acceptance of a current balance, which does exist (with some evidence indeed of unfilled needs in some areas), could well be the starting point for the report's projections. The graphical summary given on page 18 would then present an entirely different picture.

We should rise above our national tendency to be cautious and pessimistic, recognize that even a PhD may be viewed as vocational or educational (hopefully both) according to the graduates perception of the market-place, alternative opportunities, his own desires and so on, and not deliberately cut back on PhD enrolments in engineering, especially on demand data of such doubtful validity as that contained in the CEMC preliminary report. We have so little to gain and so much to lose by taking such an approach. We need to display more optimism and confidence in ourselves and in the ability of highly educated manpower to seek out and create opportunities and to raise the level of some existing positions both in government and industry. It is to be hoped that our students also will display such optimism and take a broader view of the value of their education, and that this view is shared by our federal and provincial governments. We will need this spirit if we are to move into an era in Canadian industry where increasing sophistication and high technology become more and more necessary.

NOTES

Re: 1.1

Entrance to engineering was assumed constant on a demographic base, i.e. 0.5% of male population age 15 to 19; and assumed unchanged entrance requirements.

Re: 1.2 and 1.3

The greatest danger in assuming the validity of a stable B/D ratio for projection purposes resides in the fact that the doctorate figure for the last decade includes a very large but unknown number who did not come through the Canadian baccalaureate stream. The size of that group of doctorates was related largely to immigration policies (now changed and changing), to research grants policies (which have also changed), and possibly to more selective admission policies. Perhaps a meaningful B/D ratio could usefully be established when the D number arises almost entirely from the B stream. Such data have not been collected.